

Report
on the
Capacitor & Resistor Industry



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Executive Summary

Section 854 of the 1998 Defense Authorization Act requires the Department of Defense to conduct a study of the capacitor and resistor industries in the U.S., and to submit to Congress a report on the results of that study by May 1, 1998. The report is to include an assessment of: (1) the U.S. capacitor and resistor industrial base, (2) the impact of relevant tariff reductions required by the December 1996 Information Technology Agreement (ITA), (3) the extent to which the Department of Defense (DoD) is dependent on foreign sources for its resistors and capacitors, and (4) any associated national security implications. Finally, the report is to include recommendations for appropriate changes, if any, in defense procurement policies or other Federal policies necessary to address identified national security concerns.

DoD performed its assessment primarily using industry information provided by the U.S. International Trade Commission (USITC), and, to a lesser extent, the Electronic Industries Association (EIA) and the U.S. Department of Commerce (DoC).

Capacitors and resistors represent mature technologies, available from many U.S. and foreign suppliers.

Resistors and capacitors are members of a class of electronic components referred to as passive devices. Passive devices are combined with active devices such as semiconductors to form functional circuits. Resistors and capacitors are mature, commodity products, and the technologies and processes employed in their manufacture are widely available throughout the world. They usually are produced in high volumes and orders generally are awarded to the lowest cost bidder.

Passive electronic devices are used extensively in communications equipment, computers, automobiles, consumer electronics, industrial equipment, and military systems. They are largely produced in those countries that also produce consumer electronics equipment (i.e., the U.S., Mexico, Germany, the United Kingdom, Netherlands, Japan, and other countries in the Pacific Rim). Applications for DoD account for less than one percent of world capacitor and resistor demand.

Tariff reductions likely will increase market access opportunities in the U.S. and European Union, but not in Japan.

A USITC analysis of tariff reduction impacts conducted in February 1997 concluded that ITA duty elimination likely would result in increased market access opportunities, because of the commodity nature of these products, in the U.S. and European Union. Japan already has eliminated its tariffs on capacitors and resistors; therefore, the ITA will not result in increased market access opportunities there.

However, according to U.S. industry representatives, the major Japanese consumers of passive components, large electronics Original Equipment Manufacturers,

resist purchasing products from outside of their industrial groups. Japanese passive component imports are limited mostly to products for which there are no domestic equivalents. This represents a significant non-tariff barrier for non-Japanese firms that is not considered in the ITA. Representatives of the U.S. Trade Representative have advised they will address, during the ITA review process, non-tariff barriers that might restrict access to overseas markets for U.S. exporters of capacitors, resistors, and other products covered by the ITA

DoD uses resistors and capacitors manufactured by non-U.S. suppliers.

Because of the international nature of the industry, DoD uses resistors and capacitors manufactured by non-U.S. suppliers. However, due to limitations in available data, it is not possible to determine precisely the number of such capacitors and resistors that DoD uses. DoD seldom buys capacitors and resistors directly from the manufacturer. The majority of capacitors and resistors used in defense applications are procured by lower tier subcontractors and incorporated into components or subsystems. In response to a query, EIA reported that it was unable to categorize suppliers as domestic or foreign suppliers because of an inability to accurately reflect where the product actually may have been manufactured.

- Foreign-owned firms produce devices in U.S. manufacturing facilities.
- Most large U.S. firms have extensive manufacturing facilities off-shore and import the products for sale in the U.S.
- The use of production-sharing facilities, primarily in Mexico, results in individual items with significant percentages of U.S. and non-U.S. content.
- U.S. firms distribute, relabel, and resell products produced by non-U.S. firms.

National security does not require that capacitors and resistors for DoD applications be supplied by, or be available from, U.S. firms.

Capacitors and resistors represent mature technologies, available from many U.S. and foreign suppliers – and potentially available from even more. Current and potential non-U.S. capacitor and resistor suppliers are located in Mexico, Germany, the United Kingdom, the Netherlands, Japan, and other countries in the Pacific Rim. In 1995, DoD eliminated domestic source restriction requirements for these, and other, electronic components to allow DoD to take full advantage of the benefits offered by access to the best global – primarily commercial – suppliers.

The Department believes no recommendations for changes to defense procurement policies or other Federal policies are necessary.

I. Report Requirements

Section 854 of the 1998 Defense Authorization Act requires the Department of Defense to conduct a study of the capacitor and resistor industries in the U.S., and to submit to Congress a report on the results of that study by May 1, 1998. The report is to include:

- An assessment of the industrial base for the production of resistors and capacitors within the U.S. and a projection of any changes in that base that are likely to occur after the implementation of relevant tariff reductions required by the Information Technology Agreement (ITA) entered into at the World Trade Organization (WTO) Ministerial in Singapore in December 1996.
- An assessment of the level of dependence on foreign sources for procurement of resistors and capacitors and a projection of the level of dependence on foreign sources that is likely to occur after the implementation of relevant tariff reductions required by the Information Technology Agreement.
- The implications for the national security of the United States of the projections reported above.
- Recommendations for appropriate changes, if any, in defense procurement policies or other Federal policies based on such implications.

This report responds to this requirement.

Section II. Industry Profile

Background

Resistors and capacitors are members of a class of electronic components referred to as passive devices. Passive devices are the most widely used electronic components; they are combined with active devices such as semiconductors to form functional circuits. Resistors are used to control or limit the amount of current flowing in a circuit. Capacitors are used to store and discharge energy; they are used for filtering, coupling, isolating, and storing current. Resistors and capacitors are considered to be mature, commodity products, and the technologies and processes employed in their manufacture are widely available throughout the world. They are usually produced in extremely high volumes and orders generally are awarded to the lowest bidder.

Passive electronic devices are used extensively in communications equipment, computers, automobiles, consumer electronics, industrial equipment, and military systems. They are largely produced in those countries that also produce consumer electronics equipment (i.e., the U.S., Mexico, Germany, the United Kingdom (UK), Netherlands, Japan, and other countries in the Pacific Rim).

The Department of Defense (DoD) performed its assessment primarily using industry information provided by the U.S. International Trade Commission (USITC), and, to a lesser extent, the Electronic Industries Association (EIA) and the U.S. Department of Commerce (DoC). Specifically, DoD drew extensively on industry information contained in Chapter 5 of the USITC report *Advice Concerning the Proposed Modification of Duties on Certain Information Technology Products and Distilled Spirits*, Publication 3031 dated April 1997. Chapter 5 of the USITC report is included in this report as an appendix.

U.S. Industry

The U.S. is the world's second largest manufacturer of capacitors and resistors, accounting for approximately 16 percent of world-wide production.¹ Between 1996 and 1997, U.S. capacitor sales increased about 12 percent to \$2.07 billion², while resistor sales remained relatively unchanged at about \$440 million (Figure 1).

¹ Data derived from USITC Publication 3031, dated April 1997.

² EIA Capacitor Sales - 401 reports, which exclude exports of tantalum, ceramics, mica and other fixed type and variable capacitors. 1996 report dated April 14, 1997 and 1997 report dated January 28, 1998.

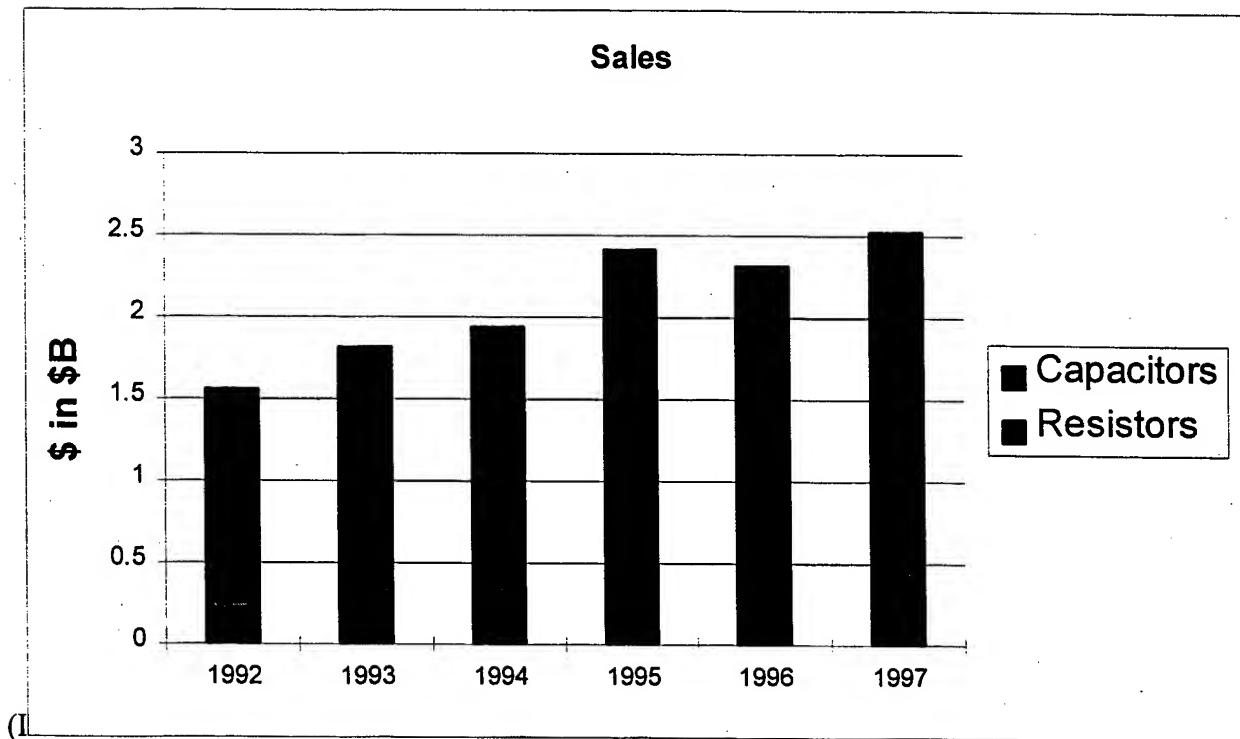


Figure 1: U.S. Capacitor and Resistor Sales - Source: USITC

Over that same period, U.S. capacitor and resistor exports increased 22 percent. The U.S. enjoyed a trade surplus of \$373 million in 1997 – a 79 percent growth over 1996 (Figure 2).³

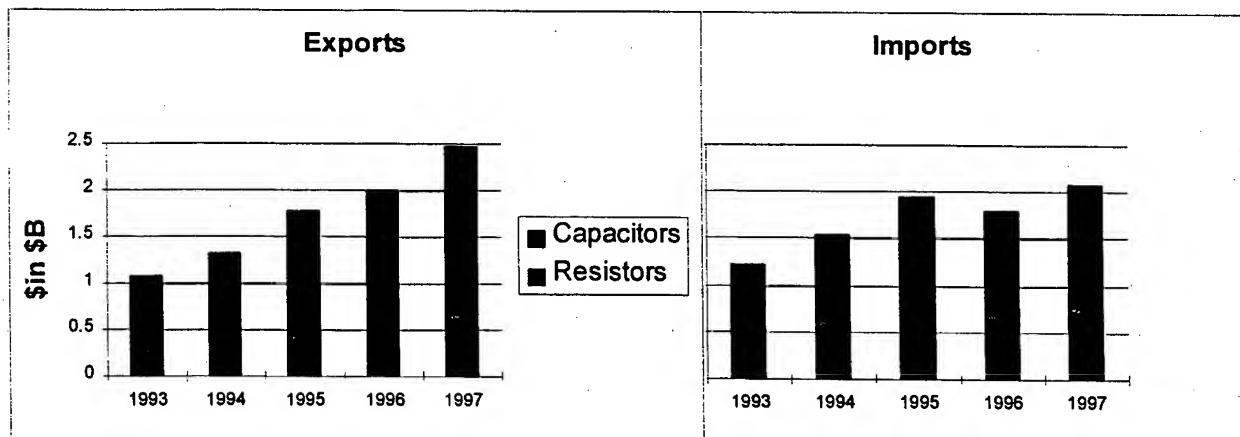


Figure 2: U.S. Capacitor and Resistor Imports and Exports - Source: DoC

The weakness in capacitor sales and decrease in capacitor imports in 1996 reflect an over supply that developed in 1995. December 1995 sales of personal computers (PCs) and cellular phones failed to meet makers' expectations and the most significant fallout hit semiconductor makers. The slump in semiconductors in turn hurt the capacitor market in 1996. Incoming

³ DoC Import and Export Data, dated March 20, 1998.

capacitor orders declined 50 percent for some items and prices fell 10-15 percent.⁴ As shown in Figure 1, sales rebounded in 1997.

The downturn in 1996 emphasizes the extent to which the commercial market influences the capacitor and resistor industry. Market experts predict that the future of passive devices is tied to the PC and burgeoning wireless communication market.⁵ DoD demand for capacitors and resistors accounted for less than one percent of the 1996 world-wide market. Consumer electronics drives the market; defense applications generally leverage commercial advances in design and manufacturing.

Mexico represents the largest U.S. export market, accounting for about 45 percent of U.S. capacitor and resistor exports.⁶ The U.S. exports finished capacitors and resistors to Mexico, typically to be incorporated into computers, televisions, and other consumer electronics equipment. However, many U.S. exports to Mexico are in the form of unfinished components which are assembled and packaged in Mexican production-sharing facilities⁷ and resold in the U.S. or elsewhere. The European Union (EU) is the second largest export market for the U.S., accounting for 15 percent of total exports. Exports to Canada comprise 10 percent of total exports. Most exports to Canada are used in the Canadian telecommunications, computer, and office equipment industries.⁸

The U.S. passive device industry is comprised of several large firms which dominate production, as well as a number of relatively small firms, most of which have annual sales under \$50 million. More than 100 companies report capacitor or resistor sales information to EIA. AVX Corporation, Kemet and Vishay Intertechnology dominate the U.S. capacitor industry, and account for approximately two-thirds of the value of U.S. production. Vishay, IRC and Bourns account for the bulk of U.S. resistor production.⁹ AVX, Kemet, and Vishay are among the world's largest producers of capacitors, and Vishay is one of the world's largest resistor manufacturers.¹⁰ Nearly all U.S. capacitor and resistor producers are "merchant firms" – suppliers which produce products to be sold to other firms, rather than for internal use. Many U.S. firms which produce capacitors also produce resistors; Vishay is the largest such producer. Domestic manufacturers often make only a few product variations because such specialization facilitates technical focus and economies of scale. Economies of scale are particularly important in an industry in which price is generally the most important factor influencing sales.

⁴ Electronic Business Today, Nov 1996 v22 n1 p7(2).

⁵ Ibid.

⁶ DoC, "Electronic Components," *North American Free Trade Agreement, Opportunities for U.S. Industries*, pages 8 - 9.

⁷ In general, production-sharing in electronic components entails dividing the fabrication and assembly processes. Manufacturing components is a relatively capital-intensive process and is conducted in the U.S.; assembling components is relatively labor-intensive and, in order to lower production costs, is conducted in a country with lower labor costs.

⁸ DoC, "Electronic Components," *North American Free Trade Agreement, Opportunities for U.S. Industries*, pages 8 - 9.

⁹ USITC Publication 3031, dated April 1997.

¹⁰ World Wide Web, retrieved Jan 1, 1997, Electronic Buyers' News, <http://www.techweb.com/se/techsearch>, "The List," *Electronic Buyers' News*, October 21, 1996.

Globalization has had a major impact on the U.S. capacitor and resistor industry. Foreign firms have acquired significant U.S. production capacity and U.S. firms have increased their international presence. Japan's Kyocera owns a majority share of the U.S. company, AVX Corporation. AVX controls roughly one-quarter of the value of U.S. capacitor production.¹¹ Additionally, Panasonic and Murata of Japan, and Philips of the Netherlands, have established sizable capacitor facilities in the U.S. Foreign firms also own considerable U.S. resistor production capabilities. A British firm owns IRC, one of the largest U.S. resistor producers.¹² Also, Japanese firms have purchased a number of former U.S. resistor producers, which no longer manufacture in the U.S.. These firms, including Rohm and DOA Speer, now are used solely to distribute Japanese-manufactured electronic components.¹³

Many U.S. capacitor and resistor manufacturers have taken steps to strengthen their position in the international market. They have established foreign facilities both to manufacture complete devices and to assemble finished devices in production-sharing operations. Table 1 lists the foreign production facilities of several large U.S. capacitor and resistor manufacturers. U.S. firms are expected to continue to establish manufacturing facilities outside the U.S. as necessary to maintain a cost competitive position in the world market, enhance customer service, avoid tariff and non-tariff barriers, take advantage of free trade agreements, capture foreign government financial incentives, and lower labor costs.¹⁴

Company	Foreign Manufacturing Facilities	Production-Sharing
AVX	Czech Republic, El Salvador, Germany, Ireland, Israel, Singapore, United Kingdom	Mexico
Kemet	Not Available	Mexico
Vishay	Canada*, Czech Republic, France, Germany, Portugal, United Kingdom	Mexico
Bourns	China, Costa Rica, Ireland, Taiwan, United Kingdom	Not Available
Aerovox	Not Available	Mexico

* Although Canada is included under the heading "Foreign Manufacturing Facilities," 10 U.S.C. 2491 defines the "national technology and industrial base" as the U.S. and Canada.

Table 1: Foreign Production Facilities of U.S. Passive Device Manufacturers - Source: USITC

U.S. firms also have entered into agreements with non-U.S. firms to distribute, relabel, and resell foreign products. For example, AVX has a distribution agreement with its Japanese parent, Kyocera, which allows AVX to use Kyocera's distribution system to market its capacitors in Japan. In return, Kyocera markets some of its components in the U.S. through AVX. Both firms benefit; they are able to offer a broader line of passive components to customers that are increasingly interested in "one-stop shopping" – the ability to purchase all or most of their

¹¹ USITC Publication 3031, dated April 1997.

¹² Ibid.

¹³ Ibid.

¹⁴ USITC Publication 3031, dated April 1997.

component needs from one or two suppliers.¹⁵ U.S. resistor firms also market products manufactured by non-U.S. suppliers. In addition to manufacturing its own resistors, Bourns sells resistors manufactured under contract with Asian producers. Bourns also imports and sells, under its name, certain resistors which Bourns does not produce. This process allows Bourns to broaden its resistor product line for customers interested in using a limited number of suppliers.¹⁶

Additionally, domestic resistor and capacitor suppliers are consolidating (for example, Rohm and DOA Speer cited above) as producers attempt to maintain a presence in multiple markets, and increase access to greater research & development (R&D) and capital resources.¹⁷

Non-U.S. Industry

In 1996, world-wide production of capacitors and resistors totaled approximately \$16.1 billion.¹⁸ Japanese firms controlled 48 percent of the production, U.S. firms controlled 16 percent, and EU firms controlled 14 percent (Figure 3).

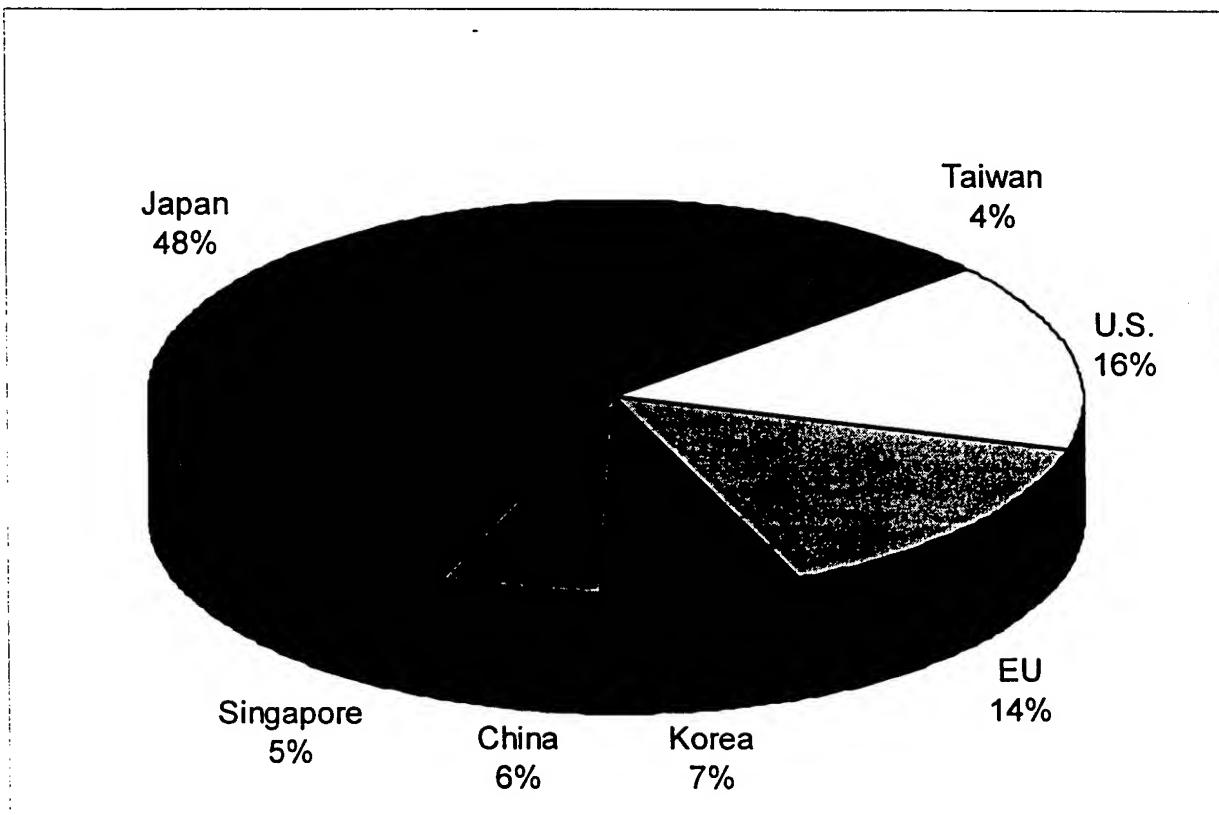


Figure 3: 1996 World Production for Capacitors & Resistors - Source: USITC

¹⁵ Ibid.

¹⁶ Ibid.

¹⁷ USITC, *Industry and Trade Summary: Capacitors*, USITC publication 2728, February 1994, page 4.

¹⁸ Estimated and reported by USITC based on official statistics of the DoC

Japan is the world's dominant producer of capacitors and resistors. Japanese firm production increased from \$6.3 billion in 1992 to \$7.8 billion in 1996, and exports exceeded \$3.5 billion in 1996.¹⁹ The Japanese industry is quite different from the U.S. industry. Japanese producers often are much larger than their U.S. competitors and frequently manufacture a wide variety of other electronic products, including "end items" such as consumer electronics. Murata, TDK Corp., Panasonic, Nippon Chemi-con, Nichicon, Kyocera, Hitachi, and Matsuo are among the largest Japanese capacitor producers. Rohm, KOA Speer, Panasonic, Fuji, Kyocera, and Susumu are the major Japanese resistor manufacturers.²⁰ To lower production cost and better serve foreign markets, Japanese firms have established foreign production facilities, increasingly in other Asian countries. For example, Kyocera purchased AVX; Murata and Panasonic maintain capacitor manufacturing facilities in the U.S.; Matsushita entered into a joint venture with Siemens of Germany to produce components in the EU; and Nissei Electric of Japan purchased Black and Decker's EU production facilities.²¹ In large part these actions have been designed to accommodate the continuing movement of Japanese consumer electronics manufacturing out of Japan.²²

Firms located in the EU represent the world's third largest block of capacitor and resistor manufacturers. EU production grew to \$2.3 billion in 1996.²³ Production is largely concentrated in Germany, the UK and the Netherlands, which are centers for EU electronic systems manufacturing. As in the U.S., the resistor and capacitor industries in the EU are a mix of EU and foreign-owned firms. Also, as in the U.S., production is dominated by a relatively small number of large producers.²⁴

Major EU capacitor manufacturers include Siemens/Matsushita, Philips, Vishay, AVX, Thomson-CSF, WIMA Arcotronics, VOX/RIFA, and ISKRA. Major EU resistor manufacturers include Philips, Vishay, Siemens, Beyschlag, Welwyn, Beckman, and Vitrohm.²⁵

Taiwan, South Korea, China, and Singapore are the largest of the emerging capacitor and resistor manufacturing nations. From 1992 to 1996, their combined production grew from \$1.7 billion to \$3.5 billion.²⁶ Taiwan is the group's largest producer of resistors, with 1996 production estimated at \$230 million.²⁷ Resistor production in Taiwan is highly fragmented with over 150 producers. The largest Taiwanese companies include Yageo, Ty-Ohm, Ever Ohms Industry, and First Resistor and Condenser Co. Ltd.²⁸ The largest South Korean producers are Samhwa Capacitor Company; vertically integrated electronics conglomerates such as Samsung, Lucky Goldstar and Daewoo; and several Japanese transplants.²⁹ For both capacitors and resistors,

¹⁹ Estimated by USITC staff based on United Nations Trade Series D.

²⁰ *Japan Electronics Almanac '95/'96* (Tokyo, Japan: Dempa Publications, Inc., 1995), page 125.

²¹ USITC Publication 3031.

²² *Japan Electronics Almanac '95/'96*, page 133.

²³ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

²⁴ USITC Publication 3031, dated April 1997.

²⁵ *Ibid.*

²⁶ Estimated by USITC staff based on Elsevier, *Yearbook of World electronics Data*, 1996.

²⁷ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronic Data*, 1996.

²⁸ Mark Lpedus, "Yageo Makes Growth Move."

²⁹ USITC, *Industry and Trade Summary; Capacitors*, page 7.

China has been the fastest growing producer, a trend that appears likely to continue. A number of companies in the region are transferring products to China to take advantage of lower production costs.³⁰ Exports from these countries more than doubled between 1992 and 1996, from \$1.2 billion to \$2.6 billion. The rate of growth in exports from these countries exceeded that of the United States, Japan and the EU.³¹

³⁰ World Wide Web, retrieved January 17, 1997, Electronic Buyer's News, <http://www.techweb.com/se/techsearch>, Marl LaPedus, "Taiwan Ups the Ante-Despite Higher Demand, Suppliers Plan Price Cuts," *Electronic Buyers' News*, February 13, 1995.

³¹ Estimated by USTIC staff based on United Nations Trade Data Series D and Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

Section III. Global Market

The production of capacitors and resistors closely follows the demand for semiconductors and the consumer electronics in which both are incorporated. Applications in computers, telecommunications equipment, automobiles, and other consumer electronics account for over three-quarters of consumption.³²

The market for capacitors and resistors in the United States increased irregularly between 1992 and 1996, with noticeable increases in 1994 and 1995, and a decline in 1996. The decline in 1996 was due to an over supply of devices resulting from weak consumer electronics sales in December 1996. Overall, U.S. market consumption grew slightly from \$2.1 billion in 1992 to \$2.4 billion in 1996.³³

Although consumption levels reflected little change, imports of capacitors and resistors increased between 1992 and 1997 (Figure 2). In 1997 the value of imports of these passive components into the U.S. equaled nearly \$2.1 billion, compared with approximately \$1.1 billion in 1992. The U.S. import to consumption ratio has increased since 1992, when capacitor and resistor imports comprised slightly over half of all U.S. consumption. By 1996, the percentage of imports to consumption increased to an estimated 71 percent.³⁴ This rise stemmed primarily from increased use of production-sharing strategies with assemblers in Mexico, plus an increase in the number of products imported from Asia for relabeling or direct sale in the United States.

Japanese consumption of capacitors and resistors remained relatively unchanged at roughly \$4.5 billion between 1992 and 1996.³⁵ Although the value of imports of passive components increased from about \$140 million in 1992 to \$300 million in 1996 – an average annual growth rate of nearly 20 percent – the import to consumption ratio in Japan remains very low. In 1992, imports comprised slightly over 3 percent of consumption, and increased to 7 percent in 1996.³⁶ Japanese imports of passive components are limited mostly to products for which there is no domestically produced equivalent.³⁷ According to U.S. industry representatives, the major Japanese consumers of passive components, large electronics Original Equipment Manufacturers (OEMs), are resistant to purchasing products from sources outside their industrial groupings.³⁸

³² World Wide Web, retrieved January 23, 1997, *Electronic Business* today, <http://www.ebt.mag.com/issue/9701/01passive.htm>, Heidi Elliot, "Passives Sing A Happy tune," *Electronic Business Today*, January 23, 1997.

³³ USITC Publication 3031, dated April 1997.

³⁴ Estimated by USITC staff based on official statistics of the USDoC.

³⁵ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996; and United Nations Trade Series D.

³⁶ Ibid.

³⁷ Ibid.

³⁸ U.S. industry representatives, telephone interviews by USITC staff, fall 1996 and winter 1997.

EU consumption of resistors and capacitors grew from \$2.5 billion in 1992 to \$3 billion in 1996, an annual average growth rate of 5 percent.³⁹ As in the U.S. market, EU consumption generally followed increased demand in the computer, telecommunications, and automobile sectors.⁴⁰ Imports represent roughly 60 percent of the EU market.⁴¹

Asian consumption, excluding Japan, grew by an average of about 14 percent between 1992 and 1996, from \$2.1 billion to \$3.6 billion.⁴² Again, growth was tied closely to growth in the consumer electronics, computers, and telecommunications industries; and for Korea and China, the automobile sectors.⁴³

³⁹ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996; and United Nations Trade Series D.

⁴⁰ USITC Publication 3031, dated April 1997.

⁴¹ European Commission, *Panorama of EU Industry*, pages 10 - 11.

⁴² Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996; and United Nations Trade Series D.

⁴³ USITC Publication 3031, dated April 1997.

Section IV. Impact of Tariff Reductions

Due to limitations in available capacitor and resistor data, it is not possible to forecast precisely the impact of ITA tariff reductions on U.S. suppliers. DoD representatives asked the EIA to estimate the impact that ITA tariff reductions would have on U.S. passive device suppliers; but it was unable to do so.⁴⁴ (EIA did, however, assert that non-tariff barriers created obstacles for U.S. firms.⁴⁵ Representatives of the U.S. Trade Representative (USTR) have advised they will address, during the ITA review process, non-tariff barriers that might restrict access to overseas markets for U.S. exporters of capacitors, resistors, and other products covered by the ITA.⁴⁶)

The USITC conducted a summary-level analysis of tariff reduction impacts in February 1997, at the request of the USTR. The USITC study included an analysis of current tariffs, an assessment of patterns of imports and exports, and an indication of potential market access opportunities resulting from proposed tariff modifications.⁴⁷ The USITC concluded that ITA duty elimination likely would result in increased market access opportunities, because of the commodity nature of these products, in the U.S. and EU, but not in Japan.⁴⁸

- U.S. tariff rates on imported capacitors were scheduled to equal 9 percent, under the General Agreement on Tariffs and Trade (GATT) Uruguay Round, on January 1, 1999. For resistors, most imports were to be dutiable at a rate of 6 percent. The ITA reduces these tariffs in steps to reach zero on January 1, 1999. Elimination of the tariffs likely will result in increased opportunities to access the U.S. market.
- The principal exporters to the EU market are firms located in Japan and the U.S., collectively accounting for approximately one-half of all EU imports.⁴⁹ Absent an ITA, capacitor imports into the EU on January 1, 1999 will be dutiable at rates ranging from a high of 3.7 percent to a low of 2.7 percent. For resistors, import tariffs will equal 2.7 percent.⁵⁰ ITA duty elimination is likely to result in increased EU market access opportunities. EU enlargement likely will further increase market access opportunities for foreign producers.

⁴⁴ EIA letter to the Department of Defense, dated February 13, 1998. (EIA did indicate that capacitor and resistor industry trends toward off-shore production mirrored those in most other high technology U.S. commodity industries. As companies employ the most cost-effective strategies to market their products, they may move manufacturing, production and assembly to non-U.S. facilities.)

⁴⁵ *Ibid.*

⁴⁶ U.S. industry representatives, interviews by DoD staff, Myrtle Beach, SC, February 3, 1998

⁴⁷ During a public comment period the USITC received comments on several subject areas, including capacitors and resistors. A number of U.S. capacitor producers expressed strong opposition to including capacitors in the agreement and one company opposed resistors. In general, these producers were concerned that the elimination of U.S. tariffs would result in substantial import growth not offset (because of the continued existence of non-tariff barriers in other major markets) by increased opportunities.

⁴⁸ USITC Publication 3031, dated April 1997.

⁴⁹ European Commission, *Panorama of EU Industry*, page 10 -9.

⁵⁰ Most-Favored-Nation Tariff Schedules

- Japan already has eliminated its tariffs on capacitors and resistors⁵¹; therefore, the ITA will not result in increased market access opportunities in Japan. However, according to U.S. industry representatives, the major Japanese consumers of passive components, large electronics OEMs, are resistant to purchasing products from outside of their industrial groups.⁵² Japanese passive component imports mostly are limited to products for which there is no domestic equivalent. This represents a significant non-tariff barrier for non-Japanese firms that is not addressed in the ITA.
- In the absence of an ITA, tariffs on capacitors and resistors are scheduled to be 13 percent in Korea and 10 percent in Singapore as of January 1, 1999.⁵³ As China and Taiwan are not WTO members, their tariff rates may change at any time. In 1992, China's base tariff rates on capacitors and resistors ranged from a high of 40 percent to a low of 15 percent. Taiwan's tariff rates in 1992 were significantly lower than China's. Capacitor and resistor duties ranged from a high of 12.5 percent to a low of 1.25 percent. Based on duty elimination under the ITA, market access opportunities should increase substantially in Taiwan, Singapore and Korea. Market access will remain unchanged in China, since it is not an ITA signatory.

⁵¹ Ibid.

⁵² USITC Publication 3031, dated April 1997.

⁵³ Most-Favored-Nation Tariff Schedules.

Section V. Foreign Dependency

Because of the international nature of the industry, DoD uses resistors and capacitors manufactured by non-U.S. suppliers. However, due to limitations in available data, it is not possible to determine precisely the number of such capacitors and resistors that DoD uses.

DoD seldom buys capacitors and resistors directly from the manufacturer. The majority of capacitors and resistors used in defense applications are procured in large quantities by lower tier subcontractors and incorporated into components or subsystems. EIA also reported that it was unable to categorize suppliers as domestic or foreign suppliers because of an inability to accurately reflect where the product actually may have been manufactured.⁵⁴ Differences in company information systems and in methods used to classify or inventory products made in the U.S. versus those imported from off-shore facilities make it extremely difficult to differentiate between capacitors and resistors produced in the U.S. and those produced elsewhere.⁵⁵

- Foreign-owned firms produce devices in U.S. manufacturing facilities.
- Most large U.S. firms have extensive manufacturing facilities off-shore and import the products for sale in the U.S.
- The use of production-sharing facilities, primarily in Mexico, results in individual items with significant percentages of U.S. and non-U.S. content.
- U.S. firms distribute, relabel, and resell products produced by non-U.S. firms.

Additionally, EIA indicated that it does not compile capacitor and resistor sales data by supplier, by government sales, or by DoD sales.⁵⁶

⁵⁴ EIA letter to the Department of Defense, dated February 13, 1998.

⁵⁵ U.S. industry representatives, interviews by DoD staff, Myrtle Beach, SC, February 2-3, 1998.

⁵⁶ Ibid.

Section VI. National Security Implications

Capacitors and resistors represent mature technologies, available from many U.S. and foreign suppliers – and potentially available from even more. DoD specifications for military-quality capacitors and resistors were changed, deliberately, in 1995 to eliminate domestic source restrictions. National security does not require that parts for DoD applications be supplied by, or be available from, only U.S. suppliers.

In an increasingly global market, DoD wants to take full advantage of the benefits offered by access to the best global suppliers and promote consistency and fairness in dealing with its allies. However, although the DoD is willing to depend on reliable foreign suppliers, it is not willing to accept foreign vulnerability or other risks to national security. DoD Handbook 5000.60-H, *Assessing Defense Industrial Capabilities*, provides guidelines which can be used to determine under what conditions national security concerns could preclude the use of reliable foreign suppliers:

- “Foreign sources may pose an unacceptable risk when there is a high “market concentration” *combined with* political or geopolitical vulnerability. A sole source supplier existing only in one physical location and vulnerable to serious political instability may not be available when needed. Note: Market concentration alone is not a reason to exclude foreign sources; there must also be a credible threat of supply disruption due to political instability. Sheer physical distance from the U.S. is *not by itself* a risk which merits foreign source exclusion ... Suppliers from politically unfriendly or anti-American foreign countries, as defined by statute or U.S. Government policy, are not used to meet U.S. defense needs.”

Current and potential non-U.S. capacitor and resistor suppliers do not meet the “exclusion criteria” described above; such suppliers are located in Mexico, Germany, the UK, the Netherlands, Japan, and other countries in the Pacific Rim. The Department sees no evidence of foreign supplier market concentration coupled with political or economic instability which could result in our access to the necessary parts being compromised (i.e., no evidence of a credible threat that supply could be disrupted). (In 1995, DoD eliminated domestic source restriction requirements for electronic components contained in DoD Manual 4120.3-M, *Defense Standardization Program Policies and Procedures*. The restriction was removed to allow DoD to utilize the best global – primarily commercial – suppliers, consistent with national security requirements.⁵⁷)

- “A U.S. source may be needed for technologies and products that are either classified, offer unique warfighting superiority, or could be used by foreign nations to develop countermeasures.”

⁵⁷ DoD letter, *Removal of On-Shore Restrictions for Established Reliability and High Reliability Electronic Components*, dated May 11, 1995.

Resistors and capacitors are mature, commodity products, and the technologies and processes employed in their manufacture are widely available throughout the world. They are usually produced in extremely high volumes and orders are generally awarded to the lowest bidder.

- “Suppliers that cannot or will not provide products for military applications for political reasons are not feasible sources.”

Current and potential suppliers willingly provide products for military applications.

Section VII. Recommendations

No recommendations for changes to defense procurement policies or other Federal policies are necessary.

In an increasingly global market, DoD wants to take full advantage of the benefits offered by access to the best global suppliers and promote consistency and fairness in dealing with its allies. Capacitors and resistors represent mature technologies available from many U.S. and foreign suppliers. National security does not require that parts for DoD applications be supplied by, or be available from, only U.S. suppliers.

APPENDIX

U.S. International Trade Commission

Washington, DC 20436

www.usitc.gov

Advice Concerning the Proposed Modification of Duties on Certain Information Technology Products and Distilled Spirits

Investigation No. 332-380



Publication 3031(Final)

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CHAPTER 5

Electronic Components

Robert Carr

Electronic components are the fundamental building blocks of the electronics industry and encompass a wide variety of products. The three main classes of electronic components include active, passive, and electro-mechanical/interconnective. Active components include semiconductors and electronic tubes. Passive components include capacitors and resistors. Electro-mechanical/interconnective components include printed circuits, connectors, relays, and switches. The three classes of components, usually working together, direct the operation of electronic products. In effect, electronic components are the functional "guts" of electronic end-products. The production of electronic components is a function of the demand for the electronic end-products and, in turn, innovations in component production are significant drivers of the markets for electronic end-products. Approximately three-quarters of electronic component production is incorporated into computers and office equipment, telecommunications equipment, and consumer electronics.¹ The remaining market for electronic components consists primarily of automotive electronics, medical equipment, avionics, measuring and analytical equipment, and military electronics.² The Information Technology Agreement (ITA) provides for the complete elimination of tariffs on certain electronic components, including semiconductors, capacitors and resistors, and printed circuits. The United States is a major producer of these components (figure 5-1), each of which is discussed in greater detail in the following sections.³

Semiconductors

Semiconductors are integral components in nearly all electronic products, including computers, communications equipment, consumer electronics, automobiles, and industrial equipment.⁴ Semiconductors have often been referred to as the "crude oil of the information age," because innovation in semiconductor technology has historically powered the evolution and performance of electronic products.⁵ Although semiconductors represent only about 17 percent of total electronics production, electronics products themselves are becoming increasingly semiconductor intensive as semiconductors are accounting for ever larger shares of the overall value of electronic products.⁶ The development of semiconductors occurred in the United States during the 1940s-1960s, and since that time, the United States has been a world leader in both production and consumption. Other major producers include Japan, the EU, and various Asian economies (figure 5-2). For a complete list of semiconductor products included in the agreement see appendix A.

¹ Integrated Circuit Engineering (ICE), Bill McLean, ed., *Mid-Term 1996, A Report on the Integrated Circuit Industry* (Scottsdale, AZ: ICE, 1996), p. 1-9; European Commission, *Panorama of EU Industry* (Luxembourg: Office for Official Publications of the European Communities, 1995), pp. 10-8 to 10-15; and estimates by USITC staff.

² Ibid.

³ The Information Technology Agreement also includes certain switching products, but as they are estimated to account for less than one-half of 1 percent of overall U.S. component production, they are not discussed here.

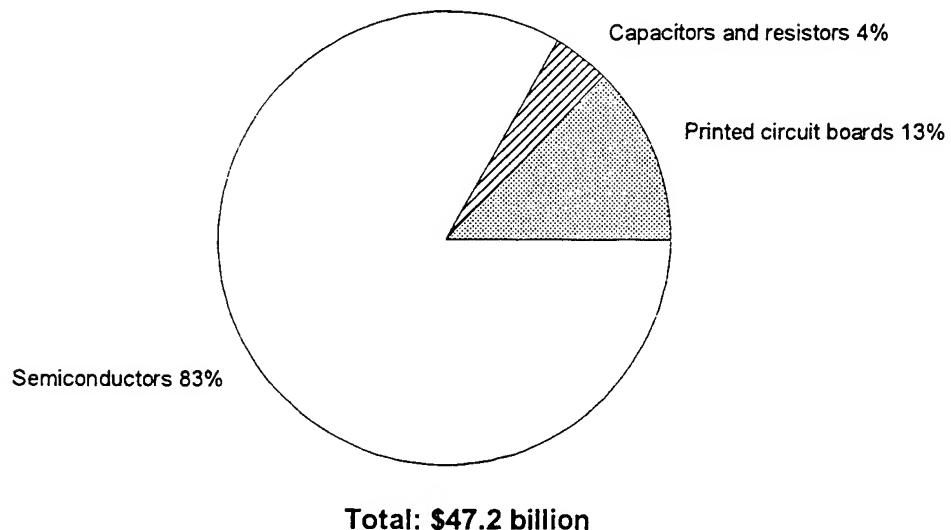
⁴ B. McLean, ed., *Mid-Term 1996*, p. 1-9.

⁵ Peter Van Zant, *Microchip Fabrication: A Practical Guide to Semiconductor Processing*, 2nd. edition (New York: McGraw-Hill, 1990), pp. 8-9 and World Wide Web, retrieved Aug. 12, 1996, Semiconductor Industry Association (SIA), <http://www.semichips.org/whatis.htm>, *What is a Semiconductor?*.

⁶ McLean, ed., *Mid-Term 1996*, p. 1-5.

Figure 5-1

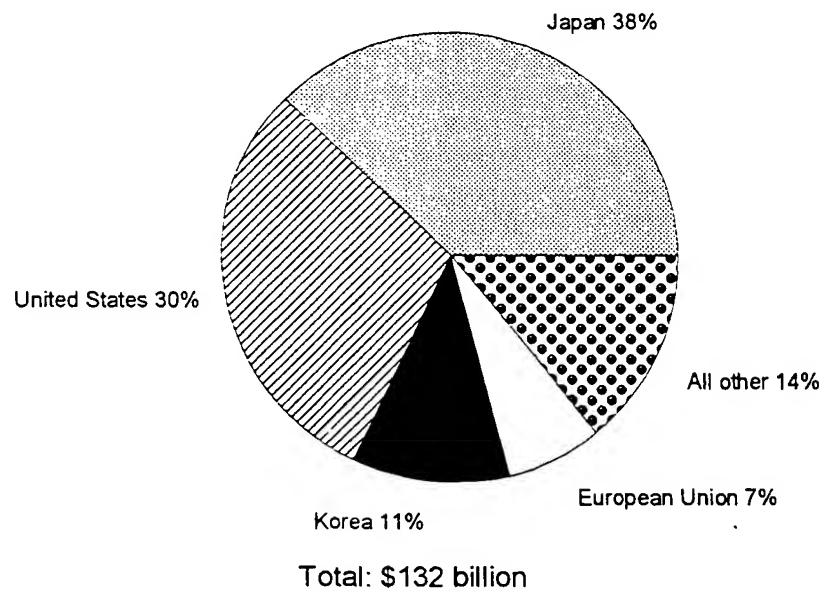
U.S. production of electronic components included in the Information Technology Agreement, 1996



Source: Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

Figure 5-2

Semiconductors: Share of world production, by major producing countries, 1996



Source: Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

The manufacture of semiconductors is a highly capital-intensive and automated process and can be divided into three stages: design, fabrication, and test and assembly.⁷ The design of a semiconductor often requires highly skilled technical employees, computer hardware, and computer-aided design (CAD) software. The fabrication process is very automated and extremely capital intensive, with the cost of a new fabrication facility, or "fab," currently estimated at \$1.2 billion. After the fabrication stage, chips are tested and assembled. Assembly includes the separation of the wafer into separate chips, packaging the chips in either plastic or ceramic, and wire bonding metal leads to the chips. Although test and assembly is quite automated, it is relatively labor intensive compared to fabrication and usually is conducted in low labor-cost countries in Asia.⁸ Depending on the diameter of the wafer and the type of semiconductor being produced, as many as 800 identical semiconductor chips may be produced simultaneously. Great effort is required to maximize wafer yield (number of working chips per wafer), especially in commodity products, because yield determines, to some extent, the price that a company must charge for its product. The higher the wafer yield, the lower the price that a producer can charge and still make a profit.

U.S. Industry Profile

The U.S. semiconductor industry, which produces a wide range of semiconductor products, faces intense international competition in nearly every product sector. The strengths of the U.S. industry are closely tied to research and development (R&D), flexibility, and a shift toward the production of noncommodity products. Although U.S. manufacturers produce a broad line of semiconductors, it is in noncommodity semiconductors that U.S. firms have become global leaders.⁹ Primarily as a result of intense Japanese competition, the bulk of the U.S. industry has shifted away from the production of commodity semiconductors and toward the production of more specialized, high value digital products. These products often require developing new technologies and the flexibility to bring a product with a short life-cycle to market quickly. U.S. firms are in the forefront of this process and are currently global leaders in the production of various specialized digital semiconductor products including high-end microprocessors, digital signal processors (DSP), programmable logic devices, and flash memory.¹⁰ Production of these devices is often lucrative due to the limited number of competitors and unit prices much higher than those of commodity semiconductors. For example, although microcomponents, a product in which U.S. firms lead in production, accounted for only 10 percent of world unit shipments in 1995, they accounted for 31 percent of the value of world shipments. In 1996, chips constructed from an 8-inch wafer devoted to 16 megabyte dynamic random access memory (DRAMs) were valued at roughly \$2,500 while the same 8-inch wafers devoted to the production of Pentium microprocessors were worth about \$26,000.¹¹ This shift in U.S. semiconductor production has coincided with the rapid growth in U.S. and world production of computer equipment and other applications which require high-end digital semiconductors. Partially as a result of this shift and reduced market volatility for high value products, the U.S. industry recovered significantly in the 1990s.

⁷ This description of semiconductor manufacturing draws upon a letter from Motorola Corp., "The Making of a Semiconductor," delivered to USITC staff, July 29, 1996, and World Wide Web, retrieved Jan. 6, 1997, Harris Semiconductor, <http://www.semi.harris.com/docs/lexicon/manufacture.html>, *How Semiconductors are Made*.

⁸ This delineation of the manufacturing process is referred to as production sharing. For a more detailed explanation of production sharing in semiconductors, see USITC, *Production Sharing: Use of U.S. Components and Materials in Foreign Assembly Operations, 1991-1994* (investigation No. 332-237), USITC publication 2966, May 1996, p. 4-9.

⁹ Arthur Gottschalk, "Asian Makers Storm Semiconductor Market," *Journal of Commerce*, Aug. 27, 1996, p. 1.

¹⁰ Michael Marks, "Industrial Policy at Work or True Grit?," *Technology Transfer Business* (Los Angeles, CA: Technology Transfer Society, Summer 1993), pp. 29-33.

¹¹ McLean, ed., *Mid-Term 1996*, p. 3-16.

According to some analysts, the U.S. industry does have certain disadvantages. Because many U.S. chip manufacturers do not produce in large volumes, they do not often achieve the production efficiencies of foreign commodity producing competitors. In addition, because most U.S. firms are not diversified out of semiconductor production, they do not have guaranteed captive consumption or the necessary financial resources to absorb a prolonged downturn in semiconductor demand.¹² However, certain U.S. producers have maintained production of commodity chips and have used it as a "process driver" to assist in improving the production efficiencies of other products. Another disadvantage for the U.S. industry is capital equipment depreciation schedules. U.S. manufacturers can fully depreciate their capital equipment in 5 years, while many of their competitors can depreciate a majority of the value of their capital equipment in 1 year. As semiconductor manufacturing equipment reportedly has an average life cycle of 3 years, U.S. manufacturers are put to a significant disadvantage.¹³

U.S. semiconductor production grew from approximately \$24 billion to \$39 billion during 1992-96 (figure 5-3).¹⁴ The downturn in U.S. production that occurred in 1996 was concurrent with the downturn in the global semiconductor market, which dropped by nearly 8 percent. Although the value of domestic shipments of semiconductors had increased by more than 60 percent during 1992-96, employment for that period only expanded by roughly 9 percent to an estimated 190,000 workers.¹⁵ This trend is reportedly due to the U.S. industry adopting increasingly capital-intensive manufacturing processes and to increases in labor productivity.¹⁶

The largest U.S. producers in 1996 were Intel, Texas Instruments (TI), Motorola, IBM, and Micron Technology, which together accounted for over one-half of the total U.S. output.¹⁷ Though there are some notable exceptions, such as TI, Motorola, and IBM, most U.S. semiconductor manufacturers specialize in the production of semiconductors and are not diversified into other industrial sectors. Most U.S. firms further specialize in the production of specific types of semiconductors, while only a few U.S. firms (IBM, Motorola, TI) offer a wide product line (table 5-1).

Semiconductor producers can be divided into captive and merchant. Merchant producers primarily sell their output on the open market, while captive firms primarily produce semiconductors for consumption in their own end-products.¹⁸ Certain U.S. producers, such as Motorola, TI, and IBM, manufacture semiconductors for both internal consumption and sale on the open market, but are generally considered to be merchants. The trend in the United States has been toward greater merchant production, which rose from 88 percent to 95 percent of total U.S. semiconductor production during 1986-1996.¹⁹

U.S. producers dominated global semiconductor production until the 1980s, when domestic production was eclipsed by that of Japan. The decline in the U.S. share of world production was also connected to the movement offshore of production facilities by many larger U.S. firms. Since the early

¹² USITC, *Industry and Trade Summary: Semiconductors*, USITC publication 2708, Dec. 1993, pp. 12-13.

¹³ World Wide Web, retrieved Feb. 19, 1997, SIA, <http://www.semichips.org/rd/taxdep.htm>, *Research and Technology*.

¹⁴ Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford, UK: Elsevier Science Ltd., 1993), 1993 ed., p. 223 and Elsevier, *Yearbook of World Electronics Data*, 1996, p. 229.

¹⁵ U.S. Department of Commerce (USDOC), *Statistical Abstract of the United States: 1996* (Washington, DC: U.S. Bureau of the Census, 1996), p. 893.

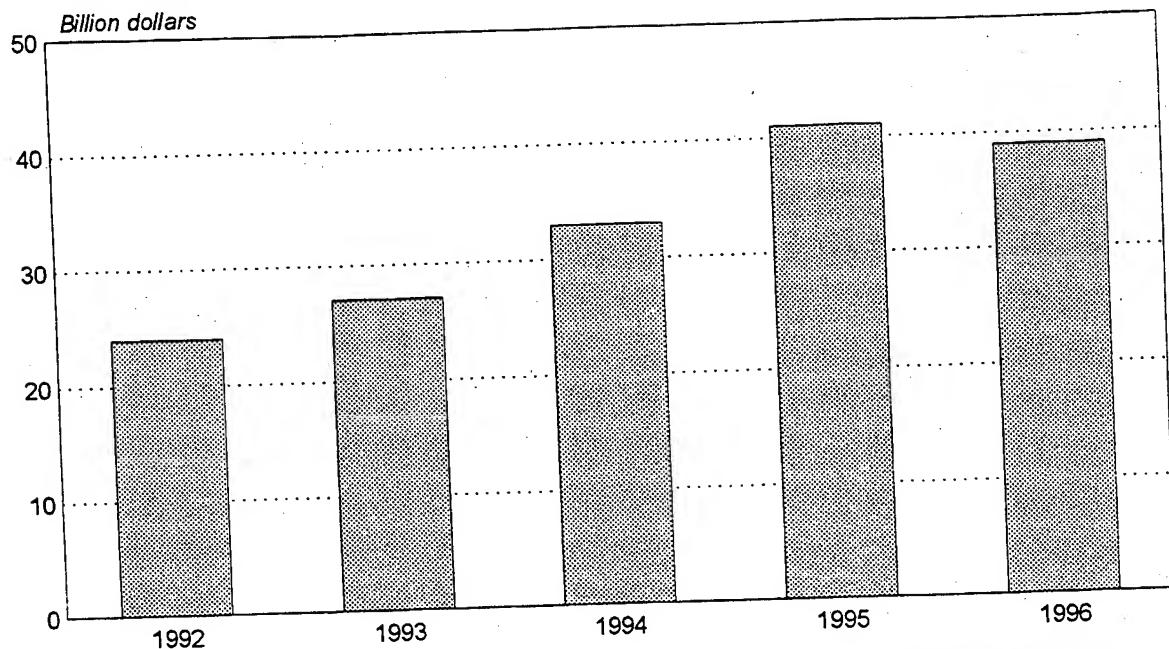
¹⁶ USITC, *Industry and Trade Summary: Semiconductors*, p. 5.

¹⁷ Estimated by USITC staff based on McLean, ed., *Mid-Term 1996*.

¹⁸ Examples of U.S. merchant firms are Intel Corp., Cirrus Logic, Advanced Micro Devices, and Harris Semiconductor. Examples of U.S. captive firms are Westinghouse, Lockheed Martin, and Delco Electronics.

¹⁹ Estimated by USITC staff based on McLean, ed., *Mid-Term 1996*.

Figure 5-3
Semiconductor: U.S. production, 1992-96



Source: Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

Table 5-1
Major U.S. merchant¹ semiconductor manufacturers, major product types, and primary end uses

Company name	Major product types	Primary end uses
AMD	Microprocessors, flash memory, logic devices	Computers, communications equipment
Analog Devices	Analog, DSPs	Consumer electronics, industrial equipment, communication equipment
Cirrus Logic	Microprocessors, DSPs	Computers, communications equipment, consumer electronics
IBM	Microprocessors, DRAMs, ASICs, ² DSPs	Computers
Intel	Microprocessors, flash memory, microcontrollers	Computers
LSI Logic	ASICs ²	Consumer electronics, computers, communications equipment
Lucent	ASICs, ² microcontrollers, logic devices	Communications equipment, consumer electronics
Micron Technology	DRAMs, SRAMs	Computers
Motorola	Microcontrollers, microprocessors, ASICs, ² SRAMs	Computers, communications equipment, automobiles
National Semiconductor	Analog, DSPs	Communications equipment, computers
Texas Instruments	DRAMs, microprocessors, DSPs, logic devices, ASICs ²	Computers, communications equipment, consumer electronics
VLSI	ASICs ²	Computers

¹ Producers who primarily sell their output on the open market.

² Application specific integrated circuits.

Source: Compiled by the staff of the USITC.

1990s, the U.S. share of world production has largely stabilized as the world demand for noncommodity semiconductors, in which U.S. firms lead in production, has risen.²⁰

Globalization has become a significant feature in the domestic and international semiconductor industry. As mentioned, U.S. firms have expanded production outside of the United States while foreign firms have opened production facilities in the United States. Most major U.S. firms have become reliant upon sales and production outside of the United States. U.S. firms locate production facilities abroad for a variety of reasons, including gaining access to foreign markets by circumventing tariff and non-tariff measures, better serving markets by locating in regions where semiconductors are being consumed, and gaining access to financing and investment incentives.²¹ For example, Intel Corp. has fabrication facilities (fabs) in the United States, Ireland, and Israel, assembly facilities in Malaysia, the Philippines, and China, and design facilities in the United States, Japan, Malaysia, and Israel.²² In addition, a number of Japanese and EU firms have located fabrication facilities in the United States, with Korean firms also expected to open fabs in the United States in the next 2 years.²³ The Japanese and Korean firms locating in the United States are largely concentrating in the production of commodity memory devices, primarily DRAMs.

Globalization in the semiconductor industry has also taken the form of strategic joint ventures and technology licensing. Semiconductor production requires significant R&D and facility investment, and a number of U.S. firms license proprietary technology to other firms or enter into joint ventures with other firms as a means of increasing revenues and spreading costs and risks. Strategic alliances also allow firms to gain access to expertise that they may be lacking such as distribution networks, design technology, and manufacturing process technology.²⁴ According to a recent DRI/McGraw-Hill study, U.S. semiconductor firms have led the way in the formation of alliances with firms headquartered in other regions, most notably with Japanese firms.²⁵ For example, IBM and Toshiba of Japan are currently engaged in a cooperative development program to produce future generations of DRAMs and are jointly funding the construction of a new fab in Virginia.²⁶ U.S. firms which are strong in specialized, noncommodity products, such as microcomponents, are also active in the licensing of these technologies to foreign producers. For example, Silicon Graphics has licensed parts of its microprocessor technology to NEC of Japan and to Philips of the Netherlands.²⁷

Globalization of the semiconductor industry has also resulted in the expansion of the value of U.S. exports. U.S. exports have more than doubled since 1992, from \$11.5 billion to an estimated \$23.5 billion in 1996.²⁸ Growth in exports during this time has been at a faster rate than the increase in U.S. production, and reflects the 120-percent increase in global semiconductor demand.²⁹ The largest U.S. export markets are Malaysia (15 percent), the EU (13 percent), Canada (12 percent), Singapore (10 percent), and Japan

²⁰ Marks, "Industrial Policy at Work or True Grit?," *Technology Transfer Business* (Los Angeles, CA: Technology Transfer Society, Summer 1993), pp. 29-33.

²¹ U.S. industry officials, interviews by USITC staff, fall/winter 1996; OECD, *Information Technology Outlook*, 1995 (Paris: OECD, 1995), p. 46; and USITC, *Industry and Trade Summary: Semiconductors*, p. 7.

²² World Wide Web, retrieved Oct. 24, 1996, Intel, <http://www.intel.com/intel/intelis/sites.htm>, Worldwide Locations.

²³ McLean, ed., *Mid-Term 1996*, pp. 2-46 to 2-48.

²⁴ World Wide Web, retrieved Feb. 2, 1997, Electronic Industries Association of Japan (EIAJ), <http://eiaj.org/study/executive.html#3>, EIAJ, DRI/McGraw-Hill Study, *The Globalization of the Semiconductor Industry, Executive Summary*.

²⁵ Ibid.

²⁶ McLean, ed., *Mid-Term 1996*, pp. 2-14 to 2-16.

²⁷ McLean, ed., *Mid-Term 1996*, p. 2-42.

²⁸ Estimated by USITC staff based on official statistics of the USDOC.

²⁹ World Wide Web, retrieved Feb. 19, 1997, SIA, <http://www.semichips.org/indstats/shares.htm>, *Chip Industry Stats* and official statistics of the USDOC.

(9 percent). Approximately one-half of U.S. exports are in the form of unfinished semiconductors. These are semiconductors that have been fabricated, but not yet assembled and packaged. After assembly, the finished semiconductors are often shipped back to the United States or other markets for final sale. Nearly 90 percent of exports to Malaysia in 1995, and substantial shares of U.S. exports to Canada, Singapore, and Japan, were in the form of unfinished products.³⁰ The primary finished products in which the United States has experienced export growth are microcomponents and flash memory.³¹

It is essential that semiconductor firms have access to the most recent technology and equipment in order to remain competitive in a business with ever shortening product cycles. As a result, the semiconductor industry is among the most technology intensive.³² New generations of DRAMs are developed about every 3 years, and each new generation requires 5 times the development costs of the previous generation.³³ Semiconductor R&D investments help to reduce product costs, accelerate product development, and shorten the time-to-market.³⁴ According to ICE, R&D expenditures accounted for nearly 12 percent of the sales of semiconductor producers in 1995, double that of the overall electronics industry.³⁵ The U.S. and Japanese industries were the two largest capital spenders in 1992, both at about \$4 billion. U.S. capital expenditures are expected to be about \$15 billion in 1996, and since 1993 the U.S. industry has outspent the Japanese industry by an estimated total of \$9 billion.

To assist U.S. producers with the great expense of R&D, two major consortia, the Semiconductor Research Corporation (SRC) and SEMATECH, have been created. SRC was formed in 1982 by the Semiconductor Industry Association (SIA), which represents the U.S. semiconductor industry. The SRC is a university research consortium which supports collegiate semiconductor research and students specializing in semiconductor technologies. SRC's current annual budget is approximately \$28 million.³⁶ SEMATECH, also a proposal of the SIA, was created in 1987. SEMATECH was initially a collaboration between 14 major U.S. semiconductor manufacturers and the U.S. Government. Its initial membership was restricted to U.S.-based firms and its goal was to improve the competitiveness of the U.S. industry. SEMATECH was funded equally by industry membership and the Federal government. Since 1987, the consortium has spent over \$2.1 billion in industry and government funds for semiconductor R&D. SEMATECH is currently in a state of change as Federal government contributions ceased in 1996, and its funding is now completely from the private sector. Also, SEMATECH has begun to relax its membership requirements. Participation in a new SEMATECH initiative to increase wafer size by 50 percent is open to any semiconductor manufacturer that has production facilities in the United States.

Although the extent of the contribution is disputed, SEMATECH and the SRC are often credited with increasing the competitiveness of U.S. producers by improving U.S. manufacturing processes and advancing the technology level of the U.S. equipment industry which supplies U.S. semiconductor producers.³⁷ Tangible improvements have been made in equipment reliability, process technology, and design

³⁰ USITC, *Shifts in U.S. Merchandise Trade in 1995* (investigation No. 332-345), USITC publication 2992, 1996, p. 11-5.

³¹ Estimated by USITC staff based on official statistics of the USDOC.

³² USITC, *Identification of U.S. Advanced-Technology Manufacturing Industries for Monitoring and Possible Comprehensive Study* (investigation No. 332-294), USITC publication 2319, 1990, p. 6.

³³ McLean, ed., *Mid-Term 1996*, pp. 3-1 to 3-6.

³⁴ USITC, *Industry and Trade Summary: Semiconductors*, p. 8.

³⁵ McLean, ed., *Mid-Term 1996*, p. 3-34.

³⁶ McLean, ed., *Mid-Term 1996*, p. 2-71.

³⁷ Marks, "Industrial Policy at Work or True Grit?", pp. 29-33.

software.³⁸ In addition, SEMATECH and the SRC have contributed to standards development and facilitated a greater willingness on the part of U.S. manufacturers to cooperate in pre-competitive technologies.

Given the great expense involved in semiconductor research, the U.S. industry is very interested in the protection of intellectual property rights. In 1984, the industry was successful in gaining the passage of the U.S. Semiconductor Chip Protection Act, which protects semiconductor layout designs, or maskworks.³⁹ In 1994, these protections were made international under the Trade Related Aspects of Intellectual Property Rights (TRIPS) code, which was agreed to under the Uruguay Round of the GATT.

The demand for and marketing of semiconductors is closely related to the demand for the products in which they are incorporated (figure 5-4).⁴⁰ Chief among these are data processing equipment (computers), communications equipment, and consumer electronics. Customized, or application specific chips, are often "designed-in" to electronics products. The design-in process often requires close collaboration between a semiconductor manufacturer and an electronics OEM (original equipment manufacturer), and can result in the direct sale of chips to the OEM. However, according to *Electronic Business Today*, well over half of all chip sales to OEMs are conducted through distributors, a trend that appears to be increasing.

Foreign Industry Profiles

Japan

Japanese producers surfaced as major competitors to U.S. firms during the late 1970s, and in the mid-1980s Japanese production overtook that of the United States.⁴¹ The Japanese industry concentrated initially on the production of commodity semiconductors, for which the manufacturing technology was fairly accessible. Japanese firms developed competitive production equipment and techniques and manufactured these products on an extremely large scale.⁴² By the late 1980s, Japanese producers were able to leverage their advantages in manufacturing efficiencies to dominate world production of volatile memory devices, DRAMs, and static random access memories (SRAMs) which in 1995 represented nearly 32 percent of global semiconductor sales.⁴³ The total value of Japanese production has increased from roughly \$35 billion to \$50 billion during 1992-96 (figure 5-5).⁴⁴ During that period, Japanese exports increased from nearly \$13 billion in 1992 to an estimated \$25 billion in 1996.⁴⁵ Japan has maintained a global lead in the production of memory devices, but has lost substantial world market share during the 1990s to Korea and Taiwan. Due in part to competition from other Asian producers as well as a shift toward greater world

³⁸ McLean, ed., *Mid-Term 1996*, p. 2-70.

³⁹ World Wide Web, retrieved Feb. 19, 1997, SIA, <http://www.semichips.org/trade/intprop.htm>, SIA, "Trade Issues."

⁴⁰ McLean, ed., *Mid-Term 1996*, p. 1-4.

⁴¹ The United States and Japan entered into a Semiconductor Arrangement on September 2, 1986 that resulted in the suspension of EPROM and 256k and above DRAM antidumping investigations and a related section 301 investigation. This arrangement, in some form, has been extended twice, most recently in August 1996.

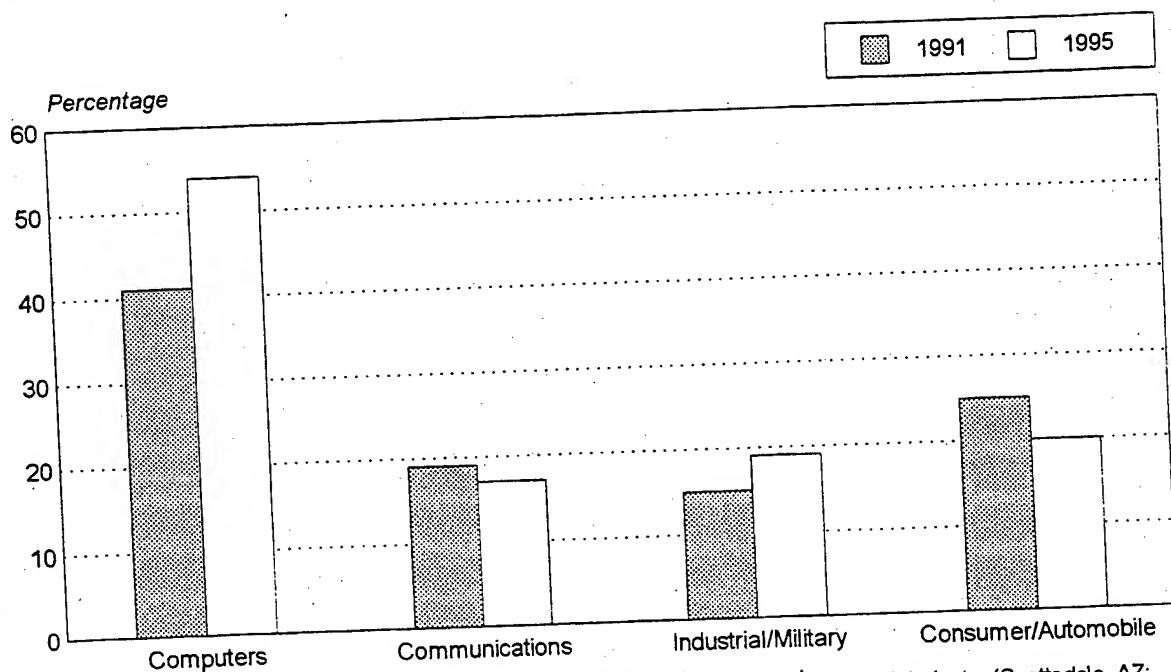
⁴² USITC, *Industry and Trade Summary: Semiconductors*, p. 10.

⁴³ USDOC, *U.S. Industrial Outlook, 1994* (Washington, DC: USDOC, 1994), p. 15-7 and estimated by USITC staff based on In-Stat Inc. This number is estimated to have dropped substantially during the global semiconductor recession of 1996, but memories still represent a sizeable portion of the entire market.

⁴⁴ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996.

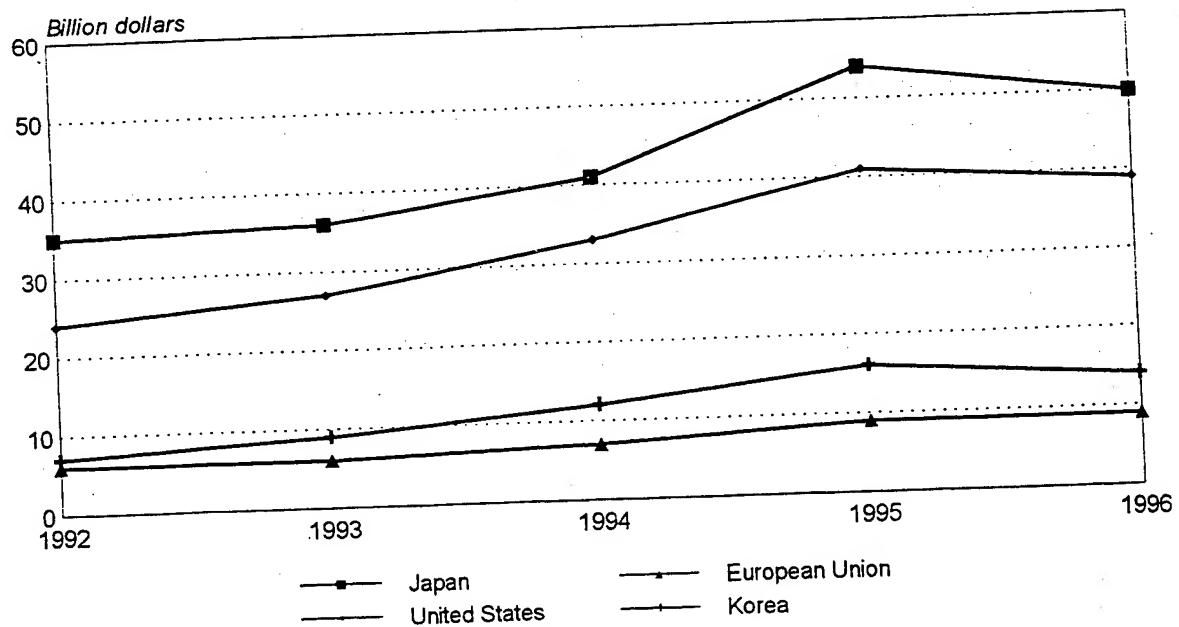
⁴⁵ Estimated by USITC staff based on United Nations Trade Series D.

Figure 5-4
Semiconductors: World usage, 1991 and 1995



Source: Integrated Circuit Engineering, *Mid-Term 1996, A Report on the Integrated Circuit Industry* (Scottsdale, AZ: ICE, 1996).

Figure 5-5
Semiconductors: Trends in production of selected producers, 1992-96



Source: Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

consumption of noncommodity products, Japan is seeking to broaden its semiconductor production into product areas that U.S. manufacturers dominate, including microcomponents, logic devices, and ASICs.⁴⁶

The structure of the Japanese industry is markedly different from that of the U.S. industry. Japanese producers of semiconductors are often large, vertically integrated firms that are members of tightly affiliated industrial groups, sometimes referred to as keiretsu. There is a large concentration among these firms, as the top ten integrated circuit manufacturers are estimated to account for nearly 82 percent of Japanese production. These firms include NEC, Hitachi, Toshiba, Mitsubishi Electric, Fujitsu, Matsushita Electronics, Sanyo Electric, Oki, Sharp, and Sony.⁴⁷ These companies all mass produce commodity devices such as DRAMs, and benefit from increased production efficiencies and process improvements associated with large economies of scale. Japanese firms are typically diversified, and produce semiconductors and other electronic components as well as the end products in which they are incorporated, such as computers and consumer electronics. The structure of the Japanese producers may offer significant advantages. Due to the high degree of captive consumption, these firms are guaranteed a certain level of demand. In addition, because of their product diversification, Japanese producers may have a greater ability than U.S. firms to weather market downturns, and greater resources to devote to R&D and capital expenses.

As is the case with U.S. producers, Japanese manufacturers depend heavily on semiconductor R&D and capital equipment spending in order to remain competitive. Like U.S. producers, Japanese producers have also organized a number of research consortia to pool resources for the development of semiconductor technology. Among these are the Association of Super-Advanced Electronics Technology (ASET) and Semiconductor Leading Edge Technologies Inc. (Selete).⁴⁸ ASET is largely dedicated to the advancement of basic process technologies, especially improvements in lithography. Selete is dedicated to the development of advanced manufacturing equipment and the enlargement of wafer sizes to 12 inches (300 mm). ASET has been opened to certain foreign-owned manufacturers located in Japan, while participation in Selete has been restricted solely to Japanese-owned firms.⁴⁹

In addition to exporting, Japanese firms, like their U.S. counterparts, are increasingly involved in other forms of international transactions. Japanese firms are entering into joint ventures and technology licensing arrangements with U.S., European, and, more recently, Korean producers, in order to gain access to new technologies and spread financial risks. Japanese firms have also become active in establishing off-shore production and assembly facilities. Japanese producers have located a number of fabrication facilities in the United States and Europe, and have established numerous production-sharing assembly facilities in Southeast Asia.

Korea

Korea has rapidly grown into a major semiconductor producer. From 1992-96, Korean semiconductor production grew from \$7 billion to an estimated \$14 billion, and Korea currently ranks third in world production.⁵⁰ Like Japan, Korea entered the semiconductor market through the production of volatile memories, DRAMs and SRAMs. Korean manufacturers have invested tremendous amounts of capital toward

⁴⁶ U.S. Department of State telegram, message reference No. 001049, prepared by U.S. Embassy, Tokyo, Feb. 5, 1997 and USDOC, *U.S. Industrial Outlook*, 1994, p. 15-7.

⁴⁷ Yano Research Institute, *Market Share in Japan 1995* (Tokyo, Japan: Yano Research Institute Ltd., 1996), p. 238.

⁴⁸ McLean, ed., *Mid-Term 1996*, p. 2-72.

⁴⁹ *Ibid.*

⁵⁰ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

the production of commodity devices and have taken advantage of large economies of scale and competitive manufacturing technologies.⁵¹

The composition of the Korean industry is unique, while the structure of the Korean companies somewhat resembles the Japanese model. There are only three major Korean semiconductor manufacturers, Samsung, Hyundai, and LG Semicon, a division of Lucky Goldstar. These three firms account for nearly 98 percent of total Korean production.⁵² They are vertically integrated conglomerates that produce a wide variety of electronic products from components to finished electronic systems such as televisions and other consumer electronics. As such, they have the financial resources to sustain downturns in the market and to make significant investments in R&D and capital equipment and other product lines to offset the down cycles in semiconductors. For example, Korean capital spending has increased from about \$1 billion in 1992 to roughly \$7 billion in 1996.⁵³ Korean firms have concentrated almost exclusively in the production of DRAMs and SRAMs, and in 1995, Samsung was the global leader in both DRAM and SRAM production. DRAMs alone are estimated to account for more than 80 percent of Korean production. Korean firms were quick to jump into commercial production of 4 megabyte and 16 megabyte DRAMs, and are currently leaders in the development of next generation 64 megabyte and 265 megabyte DRAMs.⁵⁴ During the strong memory market of 1995, Korean firms experienced over 80-percent growth in sales.⁵⁵ However, during the global downturn in the 1996 market, particularly in DRAMs, Korean firms were among the hardest hit. As a result, Korean firms are currently striving to diversify their product lines.⁵⁶

Like their foreign competitors, Korean firms are becoming increasingly active in international trade, foreign production, joint ventures, and technology licensing. Korean production is export oriented, and during 1992-96, exports grew from about \$6 billion to an estimated \$13 billion.⁵⁷ Korean producers have not established any foreign production facilities, but all three firms are in the process of doing so. Samsung and Hyundai are currently building fabrication facilities in the United States, while LG Semicon is constructing a site in the United Kingdom. In addition to establishing off-shore production facilities, Korean firms are also entering into numerous alliances with foreign producers. For example, Samsung has joined NEC in the development of ASIC products, and Hyundai has teamed with two small U.S. firms, also for the purpose of developing ASIC devices. Korean firms are interested in diversifying out of memory chips, and have begun to do so through both joint ventures and licensing agreements. Samsung has licensed ASIC and microprocessor technology from U.S. firms. Hyundai has licensed smart card technology from SGS Thomson and various technologies from Intel. LG Semicon has recently licensed microprocessor technology from Hitachi and from Advanced RISC Machines of Europe.⁵⁸

European Union

The EU is the world's fourth largest semiconductor producer, but a substantial portion of that production is attributable to foreign-owned facilities. There are only three EU-owned semiconductor

⁵¹ Marks, "Industrial Policy at Work, or True Grit," pp. 29-33.

⁵² Estimated by USITC staff based on ICE.

⁵³ Korea Economic Institute of America, *Korea's Economy 1996* (United States: Korea Economic Institute of America, 1997), pp. 45-47 and B. McLean, ed., *Mid-Term 1996*, p. 2-57.

⁵⁴ World Wide Web, retrieved Mar. 5, 1997, Electronic Industries Association of Korea (EIAK), <http://eiaak.com/overview.htm>, EIAK, *Moving Towards a Soft Landing in 1996*.

⁵⁵ McLean, ed., *Mid-Term 1996*, p. 2-46.

⁵⁶ U.S. Department of State telegram, message reference 0010049.

⁵⁷ Estimated by USITC staff based on United Nations Trade Series D.

⁵⁸ McLean, ed., *Mid-Term 1996*, pp. 2-46 to 2-51.

manufacturers among the top twenty in global production: Philips based in the Netherlands; SGS-Thomson Microelectronics, based in France and Italy; and Siemens AG, based in Germany. In addition, there are relatively few European-owned small to medium-sized producers. The largest of these are TEMIC, GEC Plessey, Ericsson, Bosch, and Alcatel, with none expected to have sales in 1996 of over \$500 million.⁵⁹ A number of leading foreign-owned firms have established production facilities in the EU including Fujitsu, Hitachi, IBM, Motorola, and TI. In general, these firms have located production in the EU in order to serve the EU market rather than to gain access to new technologies or production efficiencies. The value of EU production increased from \$6 billion in 1992 to an estimated \$9 billion in 1996, but did not keep pace with the growth trends in most other major producing regions. In general, EU-owned firms, like U.S. firms, have moved toward the production of more specialized, higher margin, application-specific devices. Currently, EU firms are among the world leaders in the production of certain non-volatile memories such as erasable programmable read only memories (EPROMs), microcontrollers, and communications ICs.⁶⁰ However, a broad variety of other products, including microprocessors and DRAMs, are also manufactured in the EU by EU-owned as well as U.S.- and Japanese-owned firms.

The structure of EU firms more closely resembles that of Japanese rather than U.S. firms. Most of the leading EU-owned semiconductor firms are diversified electronic systems manufacturers.⁶¹ Like their Japanese counterparts, they have a relatively large rate of captive consumption, which guarantees a certain level of demand.⁶² This is especially true in regard to firms such as Philips, Siemens, Ericsson, Bosch, and Alcatel.⁶³ To a certain degree, these companies have concentrated on the production of semiconductors which are most related to the end products they produce. Philips is a leader in the production of consumer electronics and concentrates its semiconductor output in logic devices and microcontrollers. Siemens, the only EU-owned manufacturer of DRAMs, is a global leader in industrial and communications electronics and has concentrated semiconductor production in microcontrollers for the industrial and automotive markets, and in communications ICs. SGS Thompson has also focused its production in semiconductors toward specific end-products, including volatile memories for computer applications, flash memory and analog ICs for communications equipment, and microcontrollers for automobiles.⁶⁴

In order to increase competitiveness, EU-owned firms are becoming increasingly involved in various forms of international transactions, including technology licensing, joint ventures, foreign production, and exporting.⁶⁵ For example, SGS-Thomson licensed its smartcard technology to Hyundai of Korea for mass production. In addition, Philips licensed microprocessor technology from Silicon Graphics that will allow Philips to produce the controlling chips necessary for the next generation of consumer electronics products.⁶⁶ Siemens has been particularly active in joint ventures. In order to spread financial risk and gain access to new technologies, Siemens has entered into an agreement with IBM and Toshiba to develop the next generation of DRAMs. Siemens has also established a joint venture with Motorola to build a DRAM facility in Richmond, Virginia. Offshore EU production is increasing with a new SGS Thompson plant to be located in Singapore and EU exports are also increasing. During 1992-96, EU exports grew from \$2.5 billion to an estimated \$5 billion.⁶⁷ This growth rate is significantly larger than the rate of growth in EU production and reflects the growing globalization of the semiconductor industry.

⁵⁹ McLean, ed., *Mid-Term 1996*, p. 2-39.

⁶⁰ McLean, ed., *Mid-Term 1996*, p. 2-40.

⁶¹ European Commission, *Panorama of EU Industry*, pp. 10-8 to 10-15.

A-1.
⁶² Arthur Gottschalk, "Asian Makers Storm Semiconductor Market," *The Journal of Commerce*, Aug. 27, 1996, p.

⁶³ Industry representative, interview by USITC staff, Dallas, TX, Dec. 2, 1996.

⁶⁴ McLean, ed., *Mid-Term 1996*, pp. 2-39 to 2-40.

⁶⁵ European Commission, *Panorama of EU Industry*, pp. 10-8 to 10-15.

⁶⁶ McLean, ed., *Mid-Term 1996*, p. 2-42.

⁶⁷ Estimated by USITC staff based on European Commission, *Panorama of EU Industry*.

Other Producers

In addition to those mentioned, there are a number of emerging semiconductor manufacturers, including Taiwan, various ASEAN countries, and China. Taiwan is quickly becoming a major producer, with output growing from about \$2 billion to \$3 billion during 1992-96.⁶⁸ The industry in Taiwan is concentrated among six firms that account for approximately 90 percent of production.⁶⁹ These firms are TSMC, UMC, Winbond, a Texas Instruments-Acer collaboration, Mosel-Vitelic, and Macronix. Current semiconductor production in Taiwan is largely in low-margin products such as SRAMs, EPROMs, and read only memories (ROMs). However, through licensing agreements, firms in Taiwan are moving toward higher margin products such as ASICs and flash memory.⁷⁰

ASEAN countries, particularly Singapore, Malaysia, and Thailand, have been the center of global production-sharing in semiconductors since the 1970s. U.S., Japanese, and EU producers ship unfinished semiconductors to these countries for testing, packaging, and re-export. However, in recent years, these countries have begun to move into fabrication as well. Most of the fabrication facilities in this region are foreign-owned transplants, but there has been the development of some domestic industry. For instance, Charter Semiconductor of Singapore recently began construction of its third fabrication facility and its 1996 output is estimated to exceed \$400 million.⁷¹

China is currently one of the fastest growing producers. Chinese manufacturing is largely in low-end areas such as the fabrication of low-tech discrete devices and contract assembly. However, major producing companies such as Intel and Motorola have made plans to locate assembly and fabrication facilities in China in the near future which may lead to further direct investment by other principal producers.

U.S. Market Profile

The United States is the world's largest consumer of semiconductors with a 1996 market estimated at \$52 billion.⁷² The 1996 figure represents an increase of nearly 85 percent over the \$28 billion total for 1992. Growth in the market for semiconductors is primarily driven by demand for the electronic systems into which they are incorporated. After negative growth in the late 1980s, the U.S. electronics systems industry has experienced growth since 1991, and double digit growth since 1994.⁷³ The primary consumers of semiconductors are the manufacturers of end-products such as computer equipment, communications equipment, industrial electronics, and automobiles.

In the United States, consumption is dominated by the computer industry, which in 1996 accounted for an estimated 70 percent of total U.S. semiconductor consumption.⁷⁴ The growing share of semiconductor consumption by the computer industry in the United States is a function of the growth of the domestic computer industry, the increasing component value of semiconductors as a share of overall computer value, and the lack of significant demand by the domestic consumer electronics industry. Computer production in the United States rose by nearly 50 percent from 1992-96. Each new generation of computer incorporates

⁶⁸ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

⁶⁹ McLean, ed., *Mid-Term 1996*, p. 2-49.

⁷⁰ McLean, ed., *Mid-Term 1996*, pp. 2-49 to 2-52.

⁷¹ McLean, ed., *Mid-Term 1996*, p. 2-53.

⁷² Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

⁷³ McLean, ed., *Mid-Term 1996*, pp. 1-3 to 1-6.

⁷⁴ McLean, ed., *Mid-Term 1996*, p. 1-10.

additional memory and processing power. For example, a personal computer in 1992 might contain 4 megabytes of DRAM while a 1996 model is typically shipped with 16 to 32 megabytes. Consequently, the semiconductor content of computers has risen to an estimated 35 percent of the sales value.⁷⁵ Other products that are driving semiconductor demand in the United States are communications equipment, especially portable phones, and automobiles, which, like computers, are becoming increasingly semiconductor intensive.

Increased consumption by the computer sector has also affected the composition of the U.S. market. Digital integrated circuits, which are used in computers, are increasing their share of the overall market. Although the demand for discrete semiconductors rose by nearly 90 percent during 1992-1996, the demand for integrated circuits grew by an estimated 140 percent. As a result, integrated circuits have increased their share of overall U.S. semiconductor consumption from 89 percent to 91 percent, while the share for discretes has dropped from 11 to 9 percent.⁷⁶ Computer applications have also contributed to the shift in the U.S. market to the greater use of digital rather than analog semiconductors.

Primarily because of the large degree of computer consumption in the U.S. market, the United States is also a leading semiconductor importer. Total U.S. semiconductor imports rose from \$15.5 billion in 1992 to an estimated \$37 billion in 1996. The largest foreign suppliers to the U.S. semiconductor market in 1996 were Japan (\$8.7 billion), Korea (\$6.2 billion), Malaysia (\$5.1 billion), and Taiwan (\$3 billion). Chief among these imports are DRAMs and SRAMs. DRAMs and SRAMs are essential components in computers but are not manufactured in large enough quantities domestically to satisfy demand. As a result, the United States fills much of its demand for these devices through imports.

The majority of DRAM and SRAM imports originate from Japan and Korea. In 1995, U.S. imports of DRAMs alone totaled over \$12 billion.⁷⁷ While imports from Japan, Korea, and Taiwan were primarily memory devices, imports from Malaysia and other Southeast Asian countries such as Singapore, Thailand, and Indonesia were largely reimports of devices fabricated in the United States and shipped to production-sharing affiliates in Southeast Asia for assembly, testing, and export back to the United States. Production sharing imports to the United States in 1995 were estimated at \$8.6 billion, or 22 percent of total imports. By 1999, the United States will have no tariffs on the importation of semiconductor devices. U.S. tariffs on semiconductors are scheduled to be eliminated under the Uruguay Round commitments by January 1, 1999. As a result, the ITA should have no impact on the opportunities for access to the U.S. market (table 5-2).⁷⁸

Foreign Market Profiles

Japan

Japan is the world's second largest consumer of semiconductors. During 1992-96, the Japanese market rose by roughly 35 percent, from \$26 billion to an estimated \$35 billion.⁷⁹ However, growth in the

⁷⁵ McLean, ed., *Mid-Term 1996*, p. 1-25.

⁷⁶ McLean, ed., *Mid-Term 1996*, p. 1-18.

⁷⁷ USITC, *Shifts in U.S. Merchandise Trade in 1995*, p. 11-5.

⁷⁸ *Most-Favoured-Nation Tariff Schedules, Annexes to Final Act Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations (Marrakesh Protocol)*, Marrakesh, Apr. 15, 1994. The Marrakesh Protocol is part of the General Agreement on Tariffs and Trade 1994 (GATT 1994), which is a multilateral agreement that is an annex to the Agreement Establishing the World Trade Organization. For tariffs on specific Harmonized Tariff Schedule categories see appendix G.

⁷⁹ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

Table 5-2
Final Uruguay Round tariffs on semiconductors for ITA participants

Participants	Ad Valorem Rate ¹ as of Jan. 1, 1999
Australia	1-15
Canada	0
Costa Rica	(²)
Estonia	0
European Communities (15)	0-14
Hong Kong	0
Iceland	0
India	40
Indonesia	40
Israel	0- ⁽²⁾
Japan	0
Korea	0
Macau	0
Malaysia	0
New Zealand	0-20
Norway	0.1-9
Romania	35
Singapore	10
Switzerland	0.1
Taiwan ³	0-2
Thailand	30- ⁽²⁾
Turkey	(²)
United States	0

¹ Ranges are indicative of the range of ad valorem rates on all products in the sector.

² Not available.

³ Taiwan has not yet acceded to the WTO. Tariff rates are based on DOC documents showing 1992 unbound rates.

Source: *Most-Favoured-Nation Schedules, Annexes of Final Act Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations, (Marrakesh Protocol)*, Marrakesh, Apr. 15, 1994 and U.S. Department of Commerce working documents.

Japanese semiconductor market has not kept pace with growth in other Asian countries, the United States, and the EU. Although the Japanese computer industry has now become the driver for semiconductor demand in Japan, representing approximately one-half of semiconductor demand, overall Japanese consumption of semiconductors has not kept pace with computer-related consumption.⁸⁰ The economic downturn in Japan and the continuing movement offshore of Japanese consumer electronics manufacturers have contributed to reduced demand from non-computer industries such as consumer electronics, communications equipment, industrial equipment and automobiles, that comprise the remainder of the Japanese market.⁸¹

During 1992-96, Japanese imports increased at a faster rate than the market. Japanese imports rose from \$4 billion to an estimated \$10 billion and imports as a portion of domestic consumption grew from 15 percent to an estimated 28 percent.⁸² The rise in imports as a share of consumption is due to the U.S.-Japan Semiconductor accords, the movement in Japan toward the predominance of computer usage of semiconductors, and the availability of low cost memories from Asian suppliers. The U.S.-Japan Semiconductor accords established mechanisms to increase foreign access to the Japanese market, including cooperative arrangements between Japanese users and foreign manufacturers as well as goals which were set for the level of foreign market share in Japan. In addition, greater consumption of computer equipment has led to greater imports, because most computers require a microprocessor as well as memory. Japanese semiconductor manufacturers are not major microprocessor manufacturers and, as a result, they are forced to import these products, largely from the United States. The same situation is true in certain telecommunications devices. Japanese semiconductor manufacturers are not leaders in the production of the chips that translate analog voice signals to digital, so are required to import these devices for consumption, most often from the United States. In recent years, low cost memory devices from Korea and Taiwan have also made headway in the Japanese market. Japan has already eliminated its tariffs on semiconductors and therefore the ITA should have no effect on market access.

European Union

The EU semiconductor market was an estimated \$19 billion in 1996.⁸³ This represents nearly a 75-percent rise over the 1992 total of \$11 billion. Semiconductor demand in the EU was driven by electronic systems production which is estimated to have grown by nearly 40 percent during 1992-96.⁸⁴ Computers and communications equipment were the primary consuming sectors and accounted for approximately 50 percent and 30 percent, respectively, of the value of EU demand.⁸⁵ The EU is largely served by U.S.-owned and Asian-owned producers. Of the top ten companies selling to the EU market, four are U.S.-owned, three are EU-owned, two are Japanese-owned, and one is Korean-owned.⁸⁶ Foreign-owned firms serve the EU market through exports as well as transplant production.

In 1996, the EU had a trade deficit in semiconductors estimated at \$10 billion.⁸⁷ Much of this deficit is a result of the lack of production in the EU of semiconductors used in computer equipment. Semiconductor imports grew in the EU during 1992-96, from an estimated \$7.5 billion to \$15 billion. The

⁸⁰ EIAJ, *Facts and Figures of the Japanese Electronics Industry* (Tokyo, Japan: EIAJ, 1996), p. 35.
⁸¹ McLean, ed., *Mid-Term 1996*, p. 1-10.

⁸² Estimated by USITC staff based on United Nations Trade Series D.

⁸³ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1992 and 1996.

⁸⁴ European Commission, *Panorama of EU Industry*, p. 10-12.

⁸⁵ McLean, ed., *Mid-Term 1996*, p. 1-10.

⁸⁶ Estimated by USITC staff based on European Commission, *Panorama of EU Industry*, p. 10-13.

⁸⁷ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1992 and 1996.

EU imports large quantities of microcomponents and memory chips.⁸⁸ In addition, the EU imports a substantial portion of its consumption of ASICs and DSPs for communications equipment. In the absence of an ITA, duties of 0 to 7 percent would remain on EU semiconductor imports with smart cards at 14 percent. As a result, market access opportunities in the EU are likely to increase. In addition, enlargement of the EU will also result in expanded market access opportunities for semiconductor producers.

Other Markets

Many of the other major semiconductor markets are located in Asia. Chief among these are Korea and Taiwan. The combined markets of these two economies grew from \$6.6 billion to an estimated \$13.5 billion during 1992-96, an increase of over 100 percent.⁸⁹

From 1992-96, the Korean market rose from \$4 billion to an estimated \$6.5 billion.⁹⁰ Korea has largely concentrated in the production of DRAMs and SRAMs, and is dependent upon foreign suppliers for other types of semiconductors. Much of Korea's semiconductor consumption is incorporated into its growing consumer electronics industry, which comprises approximately 10 percent of global consumer electronics production.⁹¹ Primary consumer electronics products include color televisions, videocassette recorders, and audio equipment. In order to meet demand, Korean imports have risen from \$3 billion in 1992 to an estimated \$5 billion in 1996.⁹² Under Uruguay Round commitments, Korea is already scheduled to eliminate its semiconductor tariffs by January 1, 1999. As a result, the ITA should have little effect on market access opportunities in Korea.

Taiwan's semiconductor market has shown significant growth, rising from \$2.6 billion in 1992 to an estimated \$7 billion in 1996.⁹³ Growth in Taiwan has been spurred by its emerging information technology industry, especially computer equipment. The largest semiconductor consumers in Taiwan include notebook computer, desktop computer, and motherboard manufacturers.⁹⁴ Like the EU market, the market in Taiwan is a competition zone for foreign manufacturers. Imports to Taiwan have grown to an estimated \$6 billion for 1996 and account for nearly 90 percent of consumption.⁹⁵ In the absence of an ITA, duties of 0 to 2 percent would remain on semiconductor imports to Taiwan. As a result, increased market access opportunities under the ITA will be negligible.

Printed Circuits

Printed circuits are usually in the form of printed circuit boards (PCBs), also referred to as printed wiring boards. Printed circuits are used to mount and interconnect other electronic components such as semiconductors, capacitors, and resistors. The printed circuit provides both the physical structure for mounting and holding electronic components as well as the electrical interconnection lines between them. Assembled, or mounted printed circuits are essential elements in nearly all electronic systems including those

⁸⁸ European Commission, *Panorama of EU Industry*, p. 10-12.

⁸⁹ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1992 and 1996.

⁹⁰ Ibid.

⁹¹ EIAK, *Moving Towards a Soft Landing in 1996*.

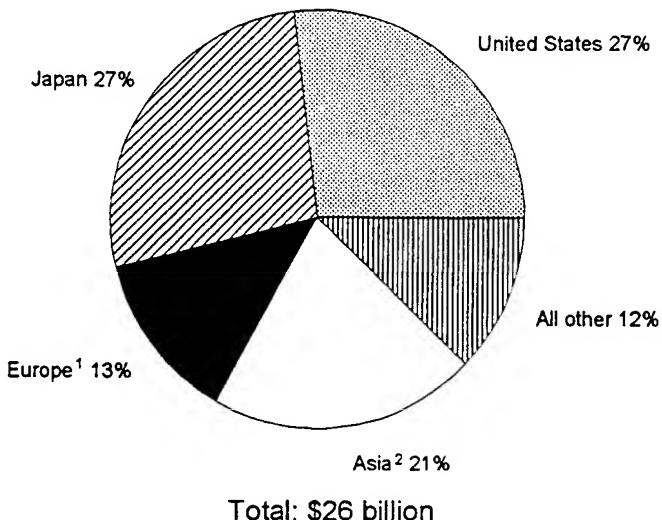
⁹² Estimated by USITC staff based on United Nations Trade Series D.

⁹³ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1992 and 1996.

⁹⁴ World Wide Web, retrieved Mar. 5, 1997, National Trade Data Bank, <http://www.stat-usa.gov/webdocs.cgi/public/market/>, USDOC, "Taiwan-Semiconductors," Feb. 1, 1995.

⁹⁵ Estimated by USITC staff based on United Nations Trade Series D and USDOC, "Taiwan-Semiconductors."

Figure 5-6
Rigid printed circuit boards: World production, 1996



¹ Europe includes Germany, the United Kingdom, Italy, and France.

² Asia includes Taiwan, China, Korea, and Singapore.

Source: USITC staff estimates based on the Institute for Interconnecting and Packaging Electronics Circuits and Elsevier Advanced Technology.

in the automotive, computer, telecommunications, consumer, medical, and aerospace industries.⁹⁶ PCBs are produced and consumed by nearly all countries engaged in the manufacture of electronics products. The United States, Japan, and the EU are the leading producers and consumers along with various Asian economies (figure 5-6). For a complete list of printed circuit products included in the agreement see appendix A.

Innovation in the PCB industry is driven largely by change in the semiconductor industry. Semiconductor devices have become increasingly more complex, with higher pin counts (input/output attachments to the PCB), narrower line-widths between circuits, and faster information cycling speeds.⁹⁷ With each new development from the semiconductor and other electronic component industries, a complementary interconnection solution is required in the form of PCB innovation or modification. Current pressures toward miniaturization, weight reduction, and portability are leading toward the use of direct attachment of uncased, bare chips onto ever smaller PCBs. These new board structures are often referred to as multichip modules (MCMs) and are likely to become increasingly important shares of the overall PCB market.⁹⁸ New technologies which allow for the attachment to the circuit board of bare, uncased components are direct chip attach and chip scale assembly.⁹⁹

⁹⁶ Printed circuits which have been assembled with components such as semiconductors, capacitors, and resistors are not classified in heading 8534 of the Harmonized Tariff Schedule. Assembled printed circuits are classified as parts of end products for which they are dedicated.

⁹⁷ USDOC, *U.S. Industrial Outlook*, 1994, p. 15-13.

⁹⁸ IPC, *The Technology Roadmap for Electronic Interconnections* (Northbrook, IL: The Institute for Interconnecting and Packaging Electronic Circuits (IPC), 1995), p. B-14.

⁹⁹ IPC, *The Technology Roadmap for Electronic Interconnections*, p. B-34.

In general, the fabrication of printed circuits is quite automated and capital intensive and can be divided into three phases: design, photography, and manufacturing.¹⁰⁰ Computer-aided design is often used to design an enlarged master of the circuit with emphasis on the placement of components. Photographs of the master are reduced and used to produce templates for the drilling of board holes and creation of circuit patterns.¹⁰¹ A copy of the circuit, usually in the form of copper, is deposited onto the board by exposing a photo-sensitive resist. Any excess deposit is then etched away. In boards of two or more layers, plated through-holes provide circuit continuity from one side of the board to the other.

U.S. Industry Profile

U.S. producers initially dominated global production of PCBs and despite a steady decline in the world market share of U.S. producers, U.S. industry remains a global leader.¹⁰² According to the market research firm Elsevier Advanced Technology, U.S. shipments of PCBs were expected to exceed \$6.2 billion in 1996, which is roughly a 20-percent increase over the \$5.2 billion total for 1992 (figure 5-7).¹⁰³ This trend represents a return to annual U.S. production increases which had been interrupted during a global PCB recession in 1989-91.¹⁰⁴

In 1996, the U.S. PCB manufacturing industry was estimated to have employed approximately 79,000 workers.¹⁰⁵ Employment was spread throughout the United States with the greatest concentration in New York and California, which combined for approximately one-half of the total.¹⁰⁶ Although the industry's domestic shipments rose by over 20 percent during 1992-1996, employment for that period grew by only about 3,000 workers.¹⁰⁷ This trend resulted from the increased production efficiencies achieved by U.S. firms through the adoption of technologies that have made manufacturing relatively more automated and capital-intensive.¹⁰⁸

As is the case with semiconductors, PCB production in the United States can be divided into merchant and captive. Merchant firms concentrate on the production of PCBs, and occasionally also the production of PCB assemblies, for sale in the open market. In contrast, captive producers are often divisions within OEMs which produce PCBs for consumption in their own end-products.¹⁰⁹ Captive U.S. producers include IBM, Lucent Technologies, Hewlett-Packard, and GM/Hughes. The merchant PCB industry in the United States is quite fragmented, with a large number of small firms. According to the Institute for Interconnecting and Packaging Electronic Circuits, (IPC), there were roughly 700 merchant producers

¹⁰⁰ The explanation of the production of PCBs draws upon the following: USITC, *Trends in International Trade in Printed Circuit Boards and Base Material Laminates*, USITC publication 1306, pp. 2-3 and L. K. Lee, "Printed Circuits," *McGraw-Hill Encyclopedia of Science and Technology* (United States: McGraw-Hill, 1987), p. 268.

¹⁰¹ A second, lesser-used method is known as the additive process.

¹⁰² Technology Marketing Research Council (TMRC), *World Market for Printed Wiring Boards and Substrate Materials, 1995* (Northbrook, IL: IPC, 1996), p. 39.

¹⁰³ Elsevier, *Yearbook of World Electronics Data*, 1993 and 1994.

¹⁰⁴ TMRC, *World Market for Printed Wiring Boards, 1995*, p. 37.

¹⁰⁵ Estimated by USITC staff based on USDOC, *Statistical Abstract of the United States: 1996* (Washington, DC: U.S. Bureau of the Census, 1996), p. 893.

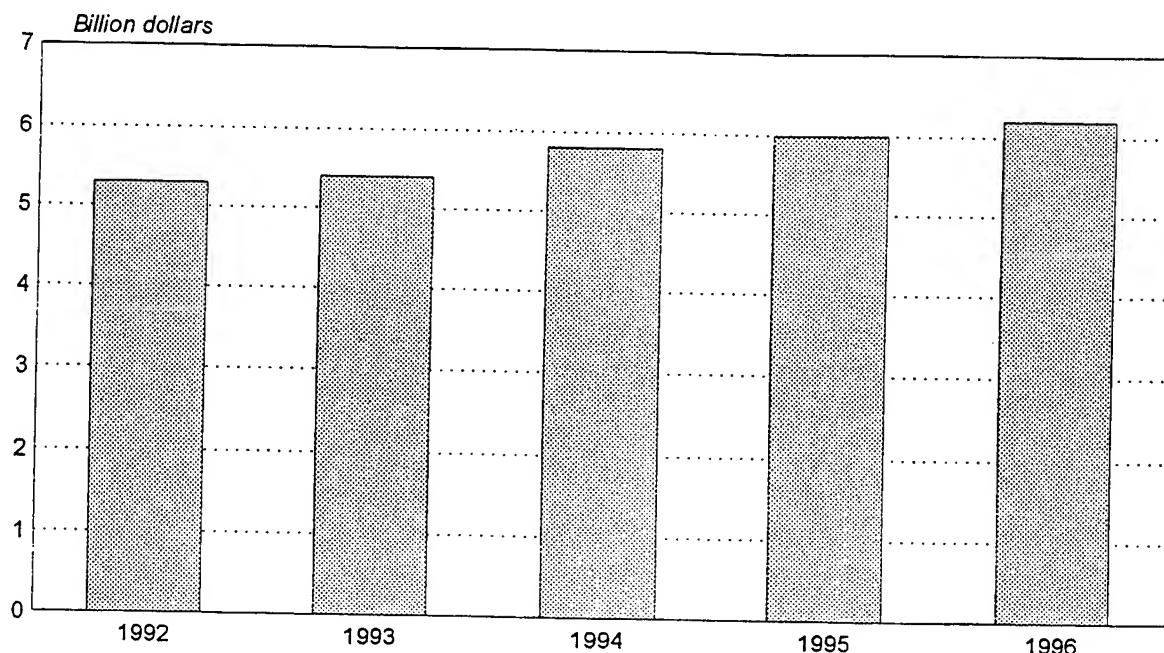
¹⁰⁶ Arsen Darnay, ed., *Manufacturing USA: Industry Analyses, Statistics, and Leading Companies* (Detroit, MI: Gale Research, 1996), p. 1890.

¹⁰⁷ USDOC, *Statistical Abstract of the United States: 1996* (5th edition), p. 893.

¹⁰⁸ *The Technology Roadmap for Electronic Interconnections*, p. C-2, and IPC representative, interview by USITC staff, Washington, DC, Jan. 17, 1997.

¹⁰⁹ USDOC, *U.S. Industrial Outlook, 1994*, p. 15-11.

Figure 5-7
Printed circuit boards: U.S. production, 1992-96



Source: Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

in the United States in 1996.¹¹⁰ Ninety percent of these firms had sales of under \$10 million each in 1995. The largest 125 merchant PCB manufacturers accounted for approximately 80 percent of all merchant production in 1995.¹¹¹ U.S. merchant firms with 1996 sales expected to exceed \$100 million include Photocircuits Corp., Hadco Corp., Zycon Corp., Merix Corp., AMP Circuit and Packaging, Viktron, and Continental.

A significant trend in the structure of the PCB industry has been the shift away from OEM production toward greater merchant production.¹¹² In 1979, captive manufacturers accounted for nearly 60 percent of U.S. production while merchant firms produced about 40 percent. In 1995, OEMs accounted for only about 20 percent of PCB production while the merchant share had increased to approximately 80 percent.¹¹³ Many OEMs have reduced or discontinued their PCB lines in the wake of the increasing costs related to PCB equipment and process modernization. OEMs have found that it is more cost-efficient to outsource their PCB needs to merchant producers than to produce the PCBs themselves.¹¹⁴ This shift in production mirrors a larger trend in U.S. electronics manufacturing where U.S. OEMs are increasingly outsourcing to contract assemblers in order to cut production costs and remain competitive.¹¹⁵

¹¹⁰ Letter from IPC representative to USITC staff, Oct. 9, 1996.

¹¹¹ USDOC, *U.S. Industrial Outlook, 1994*, p. 15-12.

¹¹² Letter from IPC representative to USITC staff, Oct. 9, 1996.

¹¹³ USDOC, *U.S. Industrial Outlook, 1994*, p. 15-12 and IPC representative, interview by USITC staff, Washington, DC, Jan. 17, 1997.

¹¹⁴ IPC representative, interview by USITC staff, Washington, DC, Jan. 17, 1997.

¹¹⁵ Assembly Marketing Research Council, *The 1995 Market for Electronics Manufacturing Service Providers/Contract Assembly Companies* (Northbrook, IL: IPC, 1996), p. 64 and report by Tim Sturgeon and Stephen Cohen, "Globalization of Electronics Manufacturing," presented at the Competitive Policy Council, Dec. 17, 1996.

Another trend has been the increase in the participation of merchant PCB makers with OEMs in the planning of future OEM products. OEMs routinely notify PCB manufacturers of their future interconnection product needs and work with them to meet those needs. This closer working relationship allows PCB manufacturers to accelerate their design and production schedule and thereby allows the OEMs to bring their products to market in a more expedited fashion.¹¹⁶ Partly because of this close working relationship, PCB sales are usually conducted directly with OEMs or contract manufacturers, though distributors are also used.¹¹⁷

U.S. manufacturers are continuing to increase the degree of automation in their industry through the use of computer aided manufacturing (CAM) and computer aided design (CAD). CAM is currently being used by nearly all PCB manufacturers, though the use and complexity varies by manufacturer. According to the IPC, U.S. producers use CAM to reduce cycle times, tooling costs, and improve product quality.¹¹⁸ CAD is used to design boards as well as to simulate electrical and thermal characteristics.¹¹⁹ However, according to the IPC, the use of CAD has not yet been fully optimized by the industry, and on the whole, automation has not been deployed by the U.S. industry to the extent found in off-shore manufacturers.¹²⁰

The production of PCBs is a function of the demand for the OEM end-products in which they are incorporated. In the United States, the computer and retail sectors have been the largest consumers of PCBs (figure 5-8), and because of the complexity of PCB requirements in computers, most U.S. PCB production has been in multi-layer form. However, increasing use of electronic components in automotive, communications, and consumer sectors have eroded the market share of computer and business equipment sector consumption. The share of PCB consumption held by the computer and business equipment sectors has dropped from approximately 50 percent in 1980 to 35 percent in 1995.

The U.S. PCB industry faces strong international competition. The strongest competition is from Asia, though competition also exists from the EU.¹²¹ After decades of global leadership in PCB production, the U.S. producers were eclipsed by Japanese producers in the late 1980s. According to the IPC, higher costs associated with labor, raw materials, and environmental safety put the industry at a disadvantage to many Asian competitors. In addition, the U.S. industry lags Japan in the use of automated process improvement techniques and in some technology areas including design-tool development, implementation, and usage.¹²² U.S. PCB manufacturers also are at a tax disadvantage in terms of equipment depreciation schedules. According to the IPC, Japanese firms are able to depreciate nearly 80 percent of the value of equipment in the first year, while U.S. firms can depreciate the value of equipment by only about 20 percent in the first year.¹²³

Another concern for U.S. PCB manufacturers is funding for R&D. Historically, large OEMs had performed much of the industry R&D. However, U.S. PCB production has largely shifted from large OEMs to small merchant firms, most of which have annual sales of under \$10 million. Many of these firms are not in a financial position to undertake comprehensive R&D projects. In response, the IPC created a PCB research consortia in 1994, the Interconnection Technology Research Institute.¹²⁴

¹¹⁶ IPC representative, interview by USITC staff, Washington, DC, Jan. 17, 1997.

¹¹⁷ IPC representative, telephone interview by USITC staff, Jan. 29, 1997.

¹¹⁸ *The Technology Roadmap for Electronic Interconnections*, p. C-1.

¹¹⁹ Ibid.

¹²⁰ *The Technology Roadmap for Electronic Interconnections*, p. D-18.

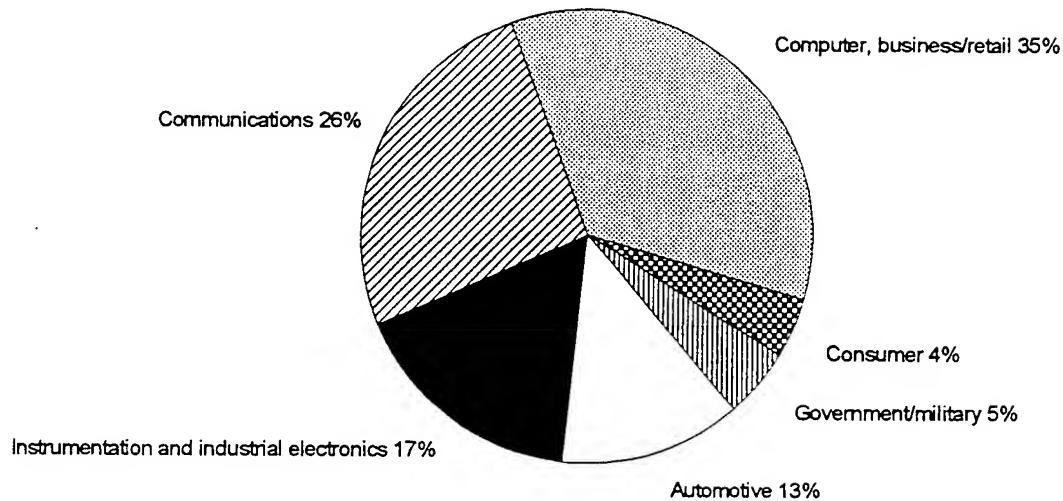
¹²¹ Letter from IPC representative to USITC staff, Oct. 9, 1996.

¹²² Ibid.

¹²³ Ibid.

¹²⁴ Ibid.

Figure 5-8
Printed circuit boards: U.S. production by end markets, 1995



Source: The Institute for Interconnecting and Packaging Electronic Circuits.

According to industry representatives, the U.S. PCB industry does have certain competitive advantages including leadership in materials development and production. In addition, it has gained important experience in the manufacture of more complex boards in response to U.S. OEM production of leading edge computer and communications equipment.¹²⁵ Also, U.S. producers often have quicker production cycles than foreign competitors due to the flexibility of relatively smaller company size.¹²⁶ Largely because of the increased production of computer and communications equipment in the United States, the U.S. PCB industry has staged a comeback and, in 1996, is estimated to have moved ahead of Japan in world market share (figure 5-9).¹²⁷

Some of the rebound of the U.S. industry can be attributed to a greater emphasis on exporting and increased export opportunities in the North American region. According to an industry representative, the U.S. industry has not been export oriented in the past.¹²⁸ This has been due in part to the relatively small size of U.S. companies and the significant resources required in developing international trading networks. However, the U.S. industry increased its efforts in this area during the 1990s.¹²⁹ In 1992, exports accounted for about 20 percent of U.S. production, but by 1996, the share had risen to almost 30 percent.¹³⁰ During that

¹²⁵ Ibid.

¹²⁶ Ibid.

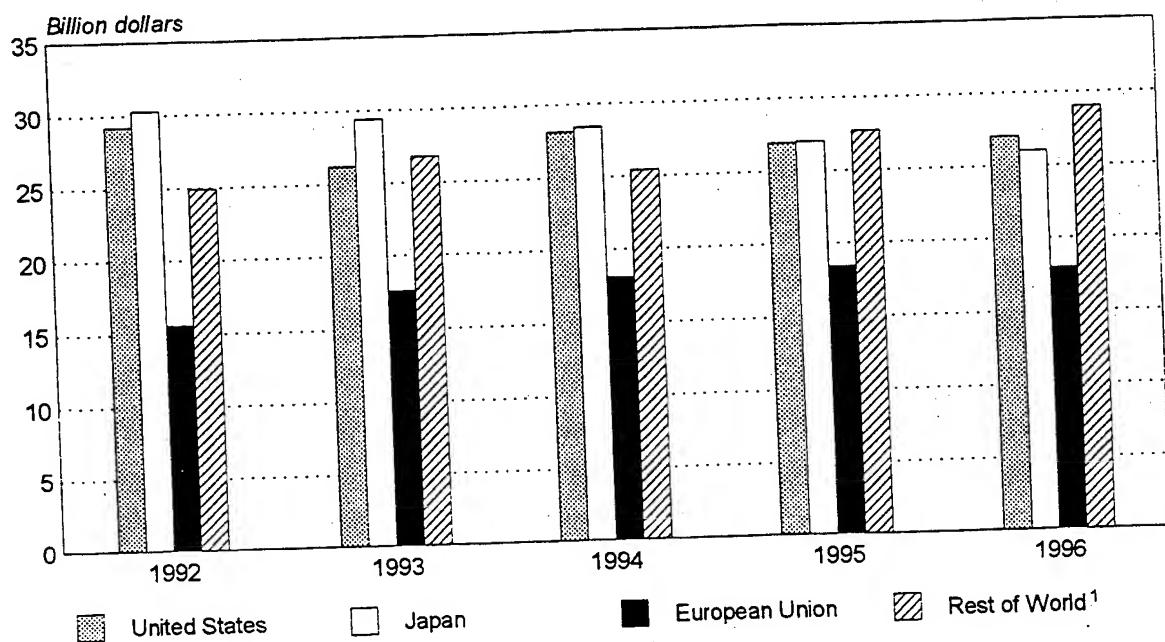
¹²⁷ TMRC, *World Market for Printed Wiring Boards and Substrate Materials, 1995*, p. 39.

¹²⁸ IPC representative, interview by USITC staff, Washington, DC, Jan. 17, 1997.

¹²⁹ Ibid.

¹³⁰ Estimated by USITC staff based on USDOC, *Current Industrial Reports MA36Q-1, Semiconductors, Printed Circuit Boards, and Related Equipment, 1995*, and official statistics of the USDOC.

Figure 5-9
Printed circuit boards: World market share by selected regions, 1992-96



¹Estimated.

Source: The Institute for Interconnecting and Packaging Electronic Circuits.

period, the value of U.S. exports grew from roughly \$1.2 billion to nearly \$1.7 billion. Over two-thirds of the growth in PCB exports can be attributed to a rise in shipments to Mexico from roughly \$91 million in 1992 to approximately \$530 million in 1996.¹³¹ The increase in exports to Mexico reflects the expansion of the maquiladora industries and their growing demand for components to incorporate into electronic end-products such as computers and televisions.¹³² Canada is the United States' second largest export market for PCBs, with the 1996 total estimated at \$525 million. Most of the PCBs exported to Canada are incorporated into telecommunications equipment, computers, and automobiles.¹³³ Canada and Mexico together accounted for nearly 60 percent of U.S. PCB exports in 1996.

Foreign Industry Profiles

Japan

Japan was the world's largest producer of PCBs for much of 1992-96. During 1992-96 Japanese PCB production grew from \$5.4 billion to an estimated \$6.1 billion (figure 5-10).¹³⁴ Japanese producers

¹³¹ Ibid.

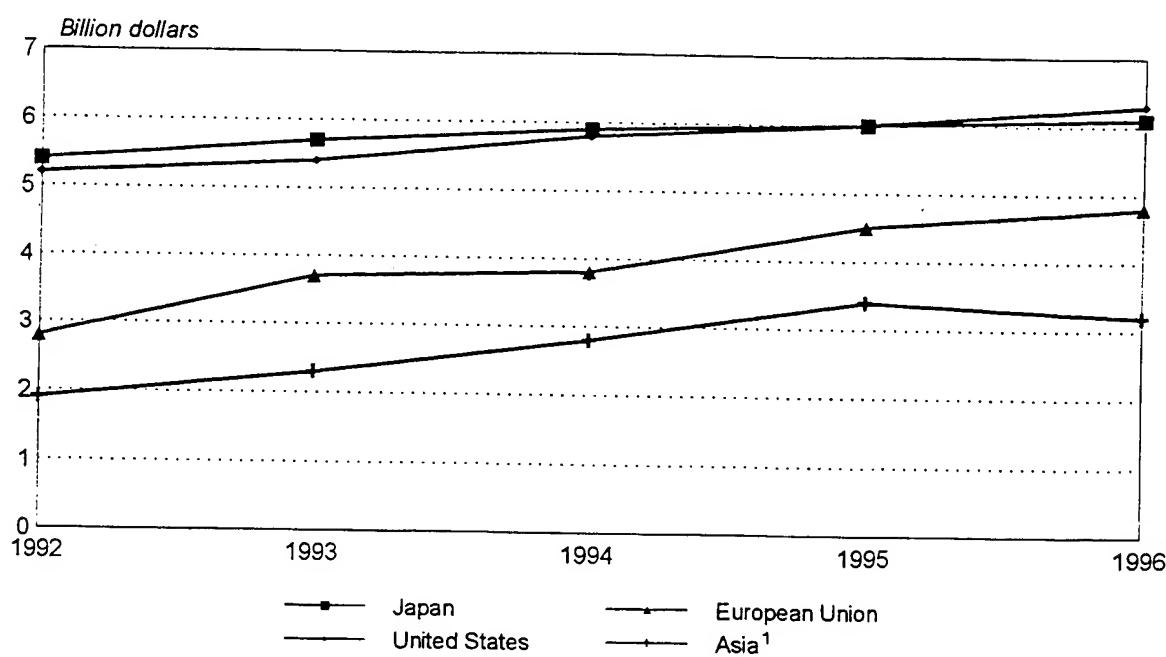
¹³² USDOC, "Electronic Components," *North American Free Trade Agreement, Opportunities for U.S. Industries* (Washington, DC: USDOC, 1993), p. 8.

¹³³ USDOC, "Electronic Components," p. 9.

¹³⁴ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1993, 1994, and 1996.

Figure 5-10

Trends in production of selected printed circuit board producers, 1992-96



¹ Includes Korea, China, Singapore, and Taiwan.

Source: USITC estimates based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

manufacture a range of PCB products including single-sided, double-sided, multi-layer, and flexible boards. Japanese firms also produce PCBs using nearly all substrates, including glass, paper, composite, and high performance materials.¹³⁵ The Japanese industry is strong in the development of design tools, their implementation, and usage. In addition, Japanese firms have been quick to adopt automated process improvement techniques that can result in increased yields and a rise in product quality.

The Japanese industry is relatively concentrated with the top ten manufacturers estimated to account for one-half of total production. Seven Japanese firms, including CMK, Hitachi, Nippon Mektron, Ibiden, Mitsubishi, Fujitsu, and Matsushita, are among the top ten in world production.¹³⁶ Other major Japanese producers include NEC, Toshiba, Sony, Toppan, and Yamamoto Manufacturing.¹³⁷ Japanese manufacturers are a mixture of captive and merchant firms. Many of the largest firms are vertically integrated conglomerates that produce entire electronic systems, of which PCBs are only a component. As such, these companies have a guaranteed level of captive consumption. Though Japan does have merchant firms, many of these firms have strong ties to Japanese electronic systems manufacturers and have thereby established a relatively stable demand within Japan.

During 1992-96, growth in Japanese exports accounted for a majority of the increases in production. While production increased by 13 percent, exports increased by nearly 150 percent, from \$650 million to \$1.6 billion. Much of the growth in exports can be attributed to growing electronics production in Asia, including the movement offshore of many Japanese consumer electronics manufacturers.

¹³⁵ TMRC, *World Market for Printed Wiring Boards and Substrate Materials*, 1995, pp. 7-17.

¹³⁶ Information provided by the IPC.

¹³⁷ TMRC, *PWBs in Asia* (Northbrook, IL: IPC, 1996).

European Union

During 1992-96, EU production of PCBs grew from \$2.8 billion to \$4.8 billion. The EU PCB industry somewhat resembles that of the United States. The EU industry is comprised of hundreds of relatively small firms. Germany alone is estimated to have as many as 300 PCB manufacturers.¹³⁸ Most of these firms have sales under \$50 million and only ten have sales of over \$100 million. Like the U.S. PCB industry, the EU industry is a mix of undiversified merchant firms and large electronics systems manufacturers. The largest EU producers include Philips, Johnson Matthey, Ericsson, ISL, Puba, and Alcatel. EU production is oriented toward PCBs for computer equipment, communications equipment, and automobiles. The EU's consumer electronics industry is relatively small, and as a result, there is little EU production of single-sided boards. The EU exports less than 10 percent of its production, with approximately 70 percent of its exports destined for developing countries. According to a U.S. industry representative, EU manufacturers are generally behind U.S. and Japanese manufacturers in design technology as well as material and tool development.¹³⁹ EU exports of PCBs grew during 1992-96, from an estimated \$200 million to \$300 million.¹⁴⁰

Other Producers

The largest of the emerging producers are located in Asia and include Taiwan, China, and Korea. Producers in this area benefit from lower manufacturing costs, including lower labor rates and less stringent environmental regulation than their competitors in Japan, the EU, and United States. Asian PCB manufacturers have also been aided by the overall increase in consumer electronics production in the region which has increased local demand for printed circuit boards.¹⁴¹

Taiwan is the group's largest PCB manufacturer, and during 1992-96 its production rose from \$1.2 billion to an estimated \$1.8 billion.¹⁴² Production in Taiwan is relatively concentrated with the top ten firms accounting for an estimated 60 percent of the total.¹⁴³ Two of these firms, Matsushita and Hitachi, are Japanese transplants. Unlike other Asian producers, Taiwan's PCB production is not heavily devoted to consumer electronics end-products. Taiwan's production is closely connected to the computer industry as an estimated 70 to 80 percent of Taiwan's PCBs are incorporated into computer equipment.¹⁴⁴ In fact, Taiwan accounts for nearly one-half of global production of PCBs used as central processing unit motherboards in personal computers. PCB firms in Taiwan are heavily export oriented with exports growing from \$600 million in 1992 to an estimated \$900 million in 1996.¹⁴⁵ However, a recent trend in Taiwan has been the movement off shore of production facilities, largely in search of lower labor rates.¹⁴⁶ Firms in Taiwan have established production facilities in China, Malaysia, and the Philippines.

China is the fastest growing member of this group with PCB output more than doubling from \$400 million in 1992 to an estimated \$900 million in 1996. Chinese PCB output is primarily focused on single-sided boards. Chinese production is largely concentrated in the Guangdong Province and exported

¹³⁸ USDOC, *U.S. Industrial Outlook*, 1994, p. 15-16.

¹³⁹ U.S. industry representative, telephone interview by USITC staff, Mar. 10, 1996.

¹⁴⁰ Estimated by USITC staff based on European Commission, *Panorama of EU Industry*, p. 10-9.

¹⁴¹ USDOC, *U.S. Industrial Outlook*, 1994, p. 15-14.

¹⁴² Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics*, 1993, 1994, and 1996.

¹⁴³ Estimated by USITC staff based on TMRC, *PWBs in Asia*.

¹⁴⁴ TMRC, *PWBs in Asia*.

¹⁴⁵ Estimated by USITC staff based on United Nations Trade Series D.

¹⁴⁶ TMRC, *PWBs in Asia*.

through nearby Hong Kong.¹⁴⁷ Chinese exports during 1992-96 rose from \$210 million to an estimated \$400 million.¹⁴⁸ The Chinese industry is highly labor-intensive with little automation. However, due to relatively low labor costs, Chinese production is very price competitive in relation to other Asian manufacturers.¹⁴⁹ The Chinese industry is comprised of over 800 different producers but the bulk of production is accounted for by foreign transplants primarily from Hong Kong, Taiwan, and Japan. Only one of the top ten Chinese producers is Chinese-owned.¹⁵⁰

The Korean industry is dominated by six producers, with the top four firms accounting for an estimated 60 percent of total production.¹⁵¹ These companies include Daeduck Electronics, Korea Circuit, Lucky Goldstar Electronics, Saehan Electronics, Cheonju Electronics, and Samsung E-Mechanics, all of which are Korean-owned. The Korean industry is concentrated in the production of single-sided boards which are largely consumed in domestic electronics equipment production.¹⁵² The majority of multilayer boards produced in Korea are exported. During 1992-96, Korean exports grew from \$70 million to an estimated \$180 million.¹⁵³ As in the case of Taiwan, in order to lower production costs through lower wage rates, Korean PCB manufacturers are establishing production facilities in Southeast Asia and Mexico.¹⁵⁴

U.S. Market Profile

The United States is the largest world market for PCBs. The U.S. market was valued at approximately \$6.5 billion in 1996, having grown at an average annual rate of approximately 5 percent from \$5.4 billion in 1992.¹⁵⁵ Most of this growth was driven by production increases in the U.S. computer and telecommunications industries, which are the largest consumers of PCBs in the United States.¹⁵⁶ U.S. production of computers and of telecommunications equipment grew at an average annual rate of more than 10 percent from 1992 and 1996.¹⁵⁷ The United States consumes few circuit boards designed for consumer electronics as it is not a major producer of such products.¹⁵⁸

U.S. imports of PCBs also have increased in recent years. From 1992 to 1996, U.S. imports of PCBs grew at an average annual rate of approximately 10 percent, from \$1.3 billion in 1992 to \$1.9 billion in 1996, comprising approximately 30 percent of U.S. consumption in 1996.¹⁵⁹ The majority of U.S. PCB

¹⁴⁷ Ibid.

¹⁴⁸ Estimated by USITC staff based on United Nations Trade Series D.

¹⁴⁹ TMRC, *PWBs in Asia*.

¹⁵⁰ Ibid.

¹⁵¹ Ibid.

¹⁵² Ibid.

¹⁵³ Estimated by USITC staff based on United Nations Trade Series D.

¹⁵⁴ TMRC, *PWBs in Asia*.

¹⁵⁵ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996.

¹⁵⁶ IPC representative, interview by USITC staff, Washington, DC, Mar. 6, 1997.

¹⁵⁷ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996.

¹⁵⁸ IPC representatives, telephone interviews by USITC staff, Jan. 29 and Mar. 6, 1997.

¹⁵⁹ USITC staff estimates based on official statistics of the USDOC. According to IPC officials, however, these import numbers may be inflated by as much as \$1 billion due to the possible misclassification of mounted circuit boards in the printed circuit board category. IPC estimates that imports in 1996 were worth approximately \$575 million and comprise closer to 10 percent of U.S. consumption. IPC representative, telephone interview by USITC staff, Mar. 7, 1997 and Technology Marketing Research Council, *The Market for Rigid Printed Wiring Boards in 1995* (Northbrook, IL: IPC, 1995), p. 57.

imports are from Taiwan and Japan, and to a lesser extent Hong Kong, Korea, and Singapore.¹⁶⁰ While imports from Japan grew from 1992 to 1996 at an average annual rate of less than 1 percent, imports from Hong Kong grew at approximately 13 percent and imports from Taiwan, Korea, and Singapore grew at close to 20 percent. Taiwan in particular has been successful in selling computer motherboards to the U.S. market. The faster import growth from these producers reportedly reflects their relative advantages vis-a-vis U.S. and Japanese producers in terms of lower labor costs, less stringent environmental regulations, and favorable government treatment, leading to lower prices.¹⁶¹ In the absence of an ITA, duties of 2.7 percent would remain in 1999 after the last stage of Uruguay Round reductions (table 5-3).¹⁶² Increase in market access opportunities under the ITA are expected to be minimal.

The U.S. PCB industry is represented by the Institute for Interconnecting and Packaging Electronic Circuits (IPC). The Commission has received a submission from the IPC that supports the ITA with certain reservations. The IPC supports the tariff elimination provisions of the ITA, but is also interested in having non-tariff barriers addressed. In addition, the IPC believes that the product landscape of the ITA was incomplete as it does not include the equipment and materials used in the manufacture of printed circuit boards. The IPC's submission can be seen in its entirety in appendix F.

Foreign Market Profiles

Japan

Japan is the second largest market in the world for PCBs. The Japanese market was valued at \$4.9 billion in 1996, having grown at an average annual rate of 4 percent from \$4.2 billion in 1992.¹⁶³ Like the United States, most PCBs are consumed in Japan by the computer and telecommunications industries, which grew at more than 10 percent and 18 percent during the period, respectively.¹⁶⁴ PCBs in Japan also are consumed by the consumer electronics industry.¹⁶⁵

While Japanese PCB imports grew at an average annual rate of 18 percent from \$100 million in 1992 to \$200 million in 1996, they comprised only 4 percent of the Japanese market in 1996.¹⁶⁶ The vast majority of Japanese imports of PCBs are from Japanese PCB subsidiaries located in other Asian countries.¹⁶⁷ Japan has already eliminated its duties on the importation of PCBs, as a result, the ITA will have no effect on increasing market access.

¹⁶⁰ While Canada is listed in official import statistics as a major source of PCB imports, IPC officials state that most imports from Canada are printed circuit board assemblies, or mounted circuit boards, which should not be classified as printed circuit boards. IPC representative, telephone interview by USITC staff, Mar. 7, 1997.

¹⁶¹ IPC representative, telephone interview by USITC staff, Mar. 6, 1997.

¹⁶² *Most-Favoured-Nation Tariff Schedules.*

¹⁶³ Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data*, 1996.

¹⁶⁴ Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data*, 1994 and 1996.

¹⁶⁵ IPC representative, telephone interview by USITC staff, Mar. 6, 1997.

¹⁶⁶ Estimated by USITC staff based on United Nations Trade Series D.

¹⁶⁷ IPC representative, telephone interview by USITC staff, Mar. 6, 1997.

Table 5-3
Final Uruguay Round tariffs on printed circuits for ITA participants

Participants	Ad Valorem Rate ¹ as of Jan. 1, 1999
Australia	17
Canada	0
Costa Rica	(²)
Estonia	0
European Communities (15)	2.7
Hong Kong	0
Iceland	(²)
India	40
Indonesia	40
Israel	10
Japan	0
Korea	8
Macau	0
Malaysia	5
New Zealand	30
Norway	3
Romania	35
Singapore	10
Switzerland	0.1-0.3
Taiwan ³	7.5
Thailand	(²)
Turkey	14.5
United States	2.7

¹ Ranges are indicative of the range of ad valorem rates on all products in the sector.

² Not available.

³ Taiwan has not yet acceded to the WTO. Tariff rates are based on DOC documents showing 1992 unbound rates.

Source: *Most-Favoured-Nation Tariff Schedules, Annexes to Final Act Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations (Marrakesh Protocol)*, Marrakesh, April 15, 1994 and U.S. Department of Commerce working documents.

European Union

The EU is the third largest world market for PCBs. The EU market, valued at \$4.2 billion in 1996, grew at an average annual rate of 7 percent from \$3.2 billion in 1992.¹⁶⁸ Like the United States, the EU PCB market has been driven by its computer, automobile, and telecommunications industries. Germany, the United Kingdom, and France consume close to 60 percent of all PCBs in the EU.¹⁶⁹

EU imports of PCBs have increased from roughly \$400 million in 1992 to an estimated \$900 million in 1996.¹⁷⁰ The major foreign suppliers to the EU market are the United States and Japan which accounted for approximately half of EU imports.¹⁷¹ In the absence of an ITA, duties of 4.5 percent would remain on EU PCB imports (table 5-4). As a result, the ITA is expected to increase market access opportunities. In addition, EU enlargement will widen the duty-free market for foreign semiconductor producers.

Other markets

Taiwan, China, and Korea are relatively small but growing consumers of PCBs; these countries' markets in 1996 were valued at \$1.1 billion, \$800 million, and \$500 million, respectively.¹⁷² The average annual growth rates of these markets from 1992 to 1996 averaged between 15 and 20 percent, due in part to their large consumer electronics industries and growing computer and telecommunications industries.

Imports of PCBs into these countries also increased substantially from 1992 to 1996, at average annual rates ranging between 20 and 30 percent.¹⁷³ In 1996, imports accounted for between one-third and one-half of total PCBs consumption. Most imports into these countries came from Singapore, Malaysia, and Hong Kong. Additionally, China is a major supplier of PCBs to the Taiwan and Korean markets.¹⁷⁴ As the United States is not a major consumer electronics PCB maker, it is also not a major PCB supplier to these countries.¹⁷⁵

Tariffs on PCBs into these countries are relatively high. China's 1992 tariffs on PCBs ranged from 25 to 40 percent, while Taiwan's tariffs were 7.5 percent.¹⁷⁶ Korean tariffs on PCBs as of January 1, 1999 will be 8 percent.¹⁷⁷ Based on duty elimination under the ITA, market access opportunities are likely to increase in Korea and Taiwan. However, market access opportunities in China should be unchanged as it is not an ITA signatory.

¹⁶⁸ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996.

¹⁶⁹ BPA (Technology & Management) Ltd., "Market Europe 1994," *PCB Service*, Dec. 1995, p. 22.

¹⁷⁰ Estimated by USITC staff based on European Commission, *Panorama of EU Industry*, p. 10-9.

¹⁷¹ IPC representative, telephone interview by USITC staff, Mar. 6, 1997, and European Commission, *Panorama of EU Industry*, p. 10-12.

¹⁷² Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996.

¹⁷³ Estimated by USITC staff based on United Nations Trade Series D.

¹⁷⁴ IPC representative, telephone interview by USITC staff, Mar. 6, 1997.

¹⁷⁵ Ibid.

¹⁷⁶ As neither of these countries are signatories to the WTO, they do not have tariff commitments. Further, these countries' tariffs are unbound, and thus can change at any time.

¹⁷⁷ *Most-Favoured-Nation Tariff Schedules*.

Capacitors and Resistors

Capacitors and resistors are passive components which perform integral functions in the operations of most electrical systems, including computers, communications equipment, automobiles, consumer electronics, and industrial equipment. They have a multitude of uses owing to their electrical characteristics, and are often used in concert with semiconductors to construct a functional circuit on a printed circuit board. Capacitors and resistors are largely produced and consumed in those countries that produce electronic systems. The United States, EU, Japan, and various other Asian countries are the leading producers and consumers (figure 5-11). For a complete list of products included in the agreement see appendix A.

Capacitors are electronic devices that have the ability to store and discharge energy. They are used for filtering, coupling, isolating, and storing current. In alternating current circuits, capacitors are often used as frequency filters, and in direct current circuits they are often used as a current blocker to isolate one portion of a circuit from another.¹⁷⁸ Capacitors are constructed either for electrical circuits, such as those used in power transmission or generation networks, or for electronic circuits, such as those used in consumer electronic goods, computers, and telecommunications equipment.¹⁷⁹ The industry producing electronic capacitors accounts for most of the value and quantity of total capacitor production.

Resistors provide resistance to the flow of electrical current. Resistors can control or limit the amount of current flowing in a circuit. In electrical circuits, resistors are often used for phase shifting. In electronic circuits, resistors are often used for voltage dropping and wave shifting. Like capacitors, most resistors are used in electronic circuits rather than in power supply applications.¹⁸⁰

The processes, equipment, and technologies used in the manufacture of capacitors and resistors depend largely on the dielectric or resistive element used in constructing the devices. Capacitors and resistors are generally considered to be mature, commodity products, and the technology used to produce them is widely available.¹⁸¹ These products are usually produced in extremely high volumes and orders are commonly awarded to the lowest bidder.

U.S. Industry Profile

U.S. production of capacitors was roughly \$1.6 billion in 1996, an increase of 23 percent over 1992's total of \$1.3 billion (figure 5-12).¹⁸² The U.S. capacitor industry employed an estimated 20,000 workers in 1996, a 7-percent increase from the 1992 level of 18,700.¹⁸³ The capacitor industry is concentrated in South Carolina, California, North Carolina, and New York. These states combined for over one-half of domestic production and employment, with South Carolina accounting for approximately 30 percent.¹⁸⁴ U.S. resistor

¹⁷⁸ World Wide Web, retrieved Jan. 16, 1997, Tech Search, <http://www.techweb.com/se/techsearch>, "Quick Guide to Capacitors," *Electronic Buyers' News*.

¹⁷⁹ *McGraw-Hill Encyclopedia of Science and Technology*, vol. 3, pp. 187-189.

¹⁸⁰ *McGraw-Hill Encyclopedia of Science and Technology*, vol. 12, pp. 380-381.

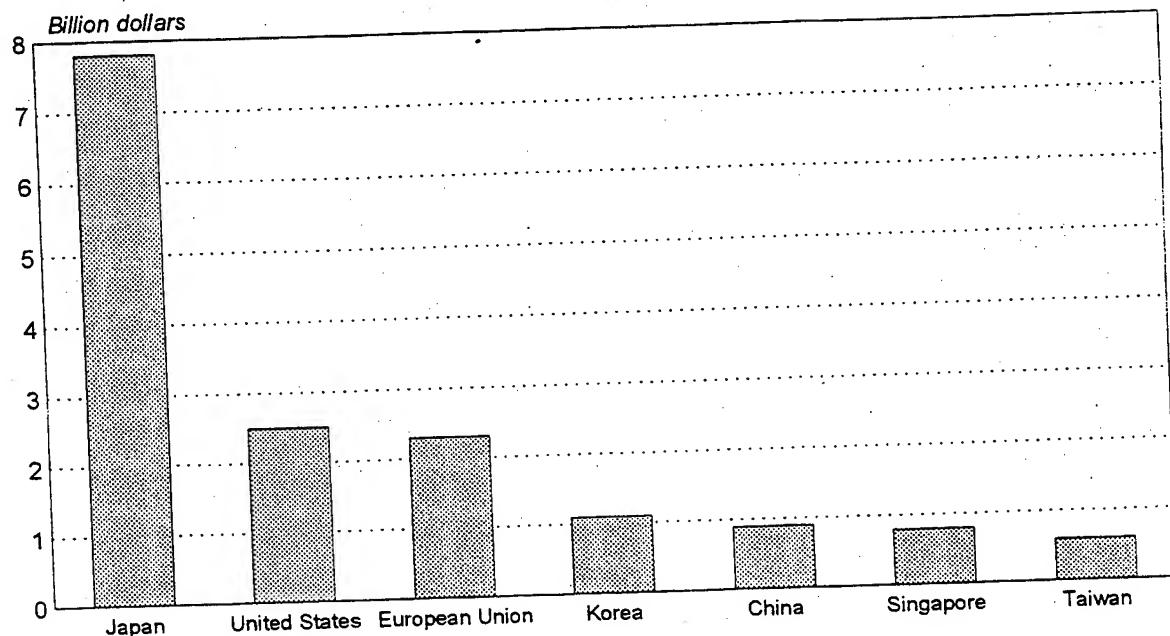
¹⁸¹ U.S. industry representatives, telephone interviews by USITC staff, fall/winter 1996.

¹⁸² Estimated by USITC staff based on official statistics of the USDOC.

¹⁸³ Bureau of Labor Statistics (BLS), *Employment and Wages Annual Averages, 1995* (Washington, DC: U.S. Dept. of Labor, 1996), p. 17, and *Employment and Wages Annual Averages, 1992* (Washington, DC: U.S. Dept. of Labor, 1993), p. 14.

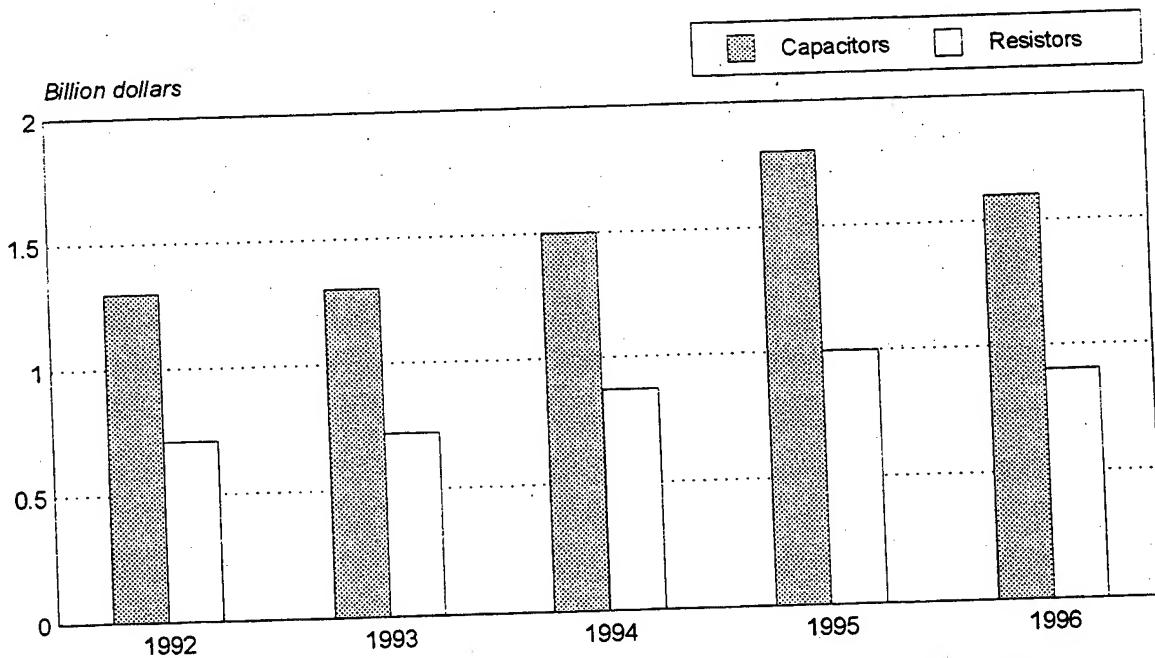
¹⁸⁴ Arsen Darnay, ed., *Manufacturing USA*.

Figure 5-11
Capacitors and resistors: Production by selected economies, 1996



Source: Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

Figure 5-12
Capacitors and resistors: U.S. production, 1992-96



Source: Estimated by USITC staff based on Elsevier Advanced Technology, *Yearbook of World Electronics Data* (Oxford: Elsevier Science Ltd., 1996).

production was roughly \$900 million in 1996, a 27 percent increase over 1992's total of \$710 million.¹⁸⁵ The U.S. resistor industry employed an estimated 10,000 workers in 1996, which was a 7-percent decrease from the 1992 level of 10,700.¹⁸⁶ Production and employment in the resistor industry is concentrated in California, Nebraska, Texas, Florida, and New Hampshire. California accounted for roughly 20 percent of U.S. production and 13 percent of employment, with no other state accounting for more than 10 percent of either production or employment.¹⁸⁷

The U.S. capacitor and resistor industries are both comprised of several large firms which dominate production as well as a number of relatively small firms, most of which have annual sales under \$50 million. AVX Corp., Kemet, and Vishay Intertechnology dominate the U.S. capacitor industry, and account for approximately two-thirds of the value of U.S. production.¹⁸⁸ The bulk of U.S. resistor production is reportedly accounted for by Vishay, IRC, and Bourns.¹⁸⁹ According to *Electronic Buyers' News*, AVX, Kemet, and Vishay are among the world's largest producers of capacitors and Vishay is one of the world's largest resistor manufacturers.¹⁹⁰ In both industries, merchant firms constitute nearly all of U.S. production and because of their end-use and customer similarities, many firms which produce capacitors also produce resistors.¹⁹¹

Globalization has had a major impact on the U.S. capacitor and resistor industries. Foreign ownership of U.S. production, the globalization of production, and increased involvement in international trade have become characteristic of both industries. Kyocera of Japan owns a majority share of AVX Corporation, the largest U.S. manufacturer of capacitors, comprising roughly one-quarter of the value of U.S. capacitor production.¹⁹² In addition, Panasonic and Murata of Japan and Philips of the Netherlands have established sizable capacitor production facilities in the United States. Foreign ownership of U.S. production is also evident in the resistor industry. IRC, reportedly one of the two largest U.S. resistor producers, is a British-owned firm.¹⁹³ Also, a number of former U.S. resistor producers have been purchased by Japanese firms and no longer manufacture in the United States. These firms, including Rohm and KOA Speer, are now used solely to distribute Japanese manufactured electronic components.¹⁹⁴

The globalization of passive component production has become commonplace, and, according to industry sources, necessary in both the capacitor and resistor industries. Globalization in production includes establishing foreign manufacturing facilities as well as production-sharing assembly facilities.¹⁹⁵ Reasons given for establishing foreign manufacturing facilities include enhancing customer service, circumventing tariff and non-tariff barriers, taking advantage of free trade agreements and foreign government financial

¹⁸⁵ Estimated by USITC staff estimates based on official data of the USDOC.

¹⁸⁶ BLS, *Employment and Wages Annual Averages, 1995*, p. 17, and BLS, *Employment and Wages Annual Averages, 1992*, p. 14.

¹⁸⁷ Arsen Darnay, ed., *Manufacturing USA*, p. 1903.

¹⁸⁸ U.S. industry representatives, telephone interviews by USITC staff, fall/winter 1996.

¹⁸⁹ U.S. industry representatives, telephone interviews by USITC staff, Jan. 1997.

¹⁹⁰ World Wide Web, retrieved Jan. 1, 1997, *Electronic Buyers' News*, <http://www.techweb.com/se/techsearch>, "The List," *Electronic Buyers' News*, Oct. 21, 1996.

¹⁹¹ World Wide Web, retrieved Jan. 17, 1997, *Electronic Buyers' News*, <http://www.techweb.com/se/search>, Mark LaPedus, "Yageo Makes Growth Move," *Electronic Buyers' News*, Oct. 16, 1995.

¹⁹² U.S. industry representatives, interviews by USITC staff, Raleigh, NC, Sept. 18, 1996.

¹⁹³ U.S. industry representatives, telephone interviews by USITC staff, Jan. 1997.

¹⁹⁴ Ibid.

¹⁹⁵ In general, production sharing in electronic components entails the division of the fabrication and assembly stages. The manufacturing of components is a relatively capital-intensive process and is conducted in the United States. The assembly of components is relatively labor-intensive and, in order to lower production costs, is conducted in a country with lower labor costs.

incentives, and lowering labor costs. Most major U.S. capacitor and resistor manufacturers have established international production operations (table 5-4). These firms have stated that the use of production-sharing facilities in lower wage countries and the establishment of manufacturing facilities in the regions where their products are marketed are essential to their ability to successfully compete internationally.¹⁹⁶ By using production-sharing operations, firms can effectively reduce labor and overall production costs in what are very price sensitive products. Also, locating in close proximity to customers allows for greater producer-consumer interaction and can result in improved customer service by facilitating faster responses to customer needs.

U.S. exports of capacitors and resistors reflect the trend toward production sharing and increased international transactions. Capacitor and resistor exports doubled from \$900 million in 1992 to an estimated \$1.8 billion in 1996 (figure 5-13).¹⁹⁷ By far, the largest market for U.S. exports is Mexico, which in 1996 was estimated to account for nearly 45 percent of the total. Reflecting the growth in the maquiladora electronics industries, U.S. exports to Mexico have grown from \$270 million in 1992 to an estimated \$910 million in 1996. U.S. exports to Mexico of finished capacitors and resistors are typically incorporated into computers, televisions, and other consumer electronics equipment.¹⁹⁸ Many of the exports to Mexico are in the form of unfinished components, which are usually assembled and packaged in Mexican production-sharing facilities and resold in the United States or elsewhere. The EU is the United States' second largest export market and accounts for roughly 15 percent of the total. Canada is third with 10 percent. Most of the exports to Canada are consumed by the Canadian telecommunications, computer, and office equipment industries.¹⁹⁹

U.S. firms are also participating in international transactions in the form of distribution agreements and the resale of foreign produced products. AVX has a distribution agreement with its Japanese parent, Kyocera. The agreement allows AVX to use Kyocera's distribution system to market its products in Japan. In return, Kyocera markets some of its components through AVX in the United States. Both parties benefit, as they are able to offer a broader line of passive components to customers that are increasingly interested in one-stop shopping, the ability to purchase all or most of their component needs from one or two suppliers.²⁰⁰ U.S. resistor firms are also involved in marketing foreign-manufactured product. In addition to manufacturing its own resistors, Bourns currently sells resistors manufactured under contract with Asian producers. Certain resistors, which Bourns does not produce, are imported and sold under the Bourns name. This process allows Bourns to broaden its resistor product line for customers interested in using a limited number of suppliers.²⁰¹

U.S. manufacturers of capacitors and resistors often concentrate in the production of only a few varieties of their products. Specialization allows for greater economies of scale and greater technical focus. In the case of capacitors, specific types often require distinctive production processes and are most suited for certain end products. For example, ceramic and tantalum capacitors are most used in information technology products such as computers, cell phones, and automobiles, while aluminum and film capacitors are most often used in industrial applications such as air conditioners, motors, fluorescent lighting, and compressors. AVX,

¹⁹⁶ U.S. industry representatives, interviews by USITC staff, Myrtle Beach, SC, Feb. 11, 1997.

¹⁹⁷ Estimated by USITC staff based on official statistics of the USDOC.

¹⁹⁸ USDOC, "Electronic Components," *North American Free Trade Agreement, Opportunities for U.S. Industries*, pp. 8-9.

¹⁹⁹ Ibid.

²⁰⁰ U.S. industry representatives, interviews by USITC staff, Myrtle Beach, SC, Feb. 11, 1997, and U.S. industry representatives, telephone interviews by USITC staff, Jan. 1997.

²⁰¹ U.S. industry representatives, telephone interviews by USITC staff, Jan. 1997.

Table 5-4

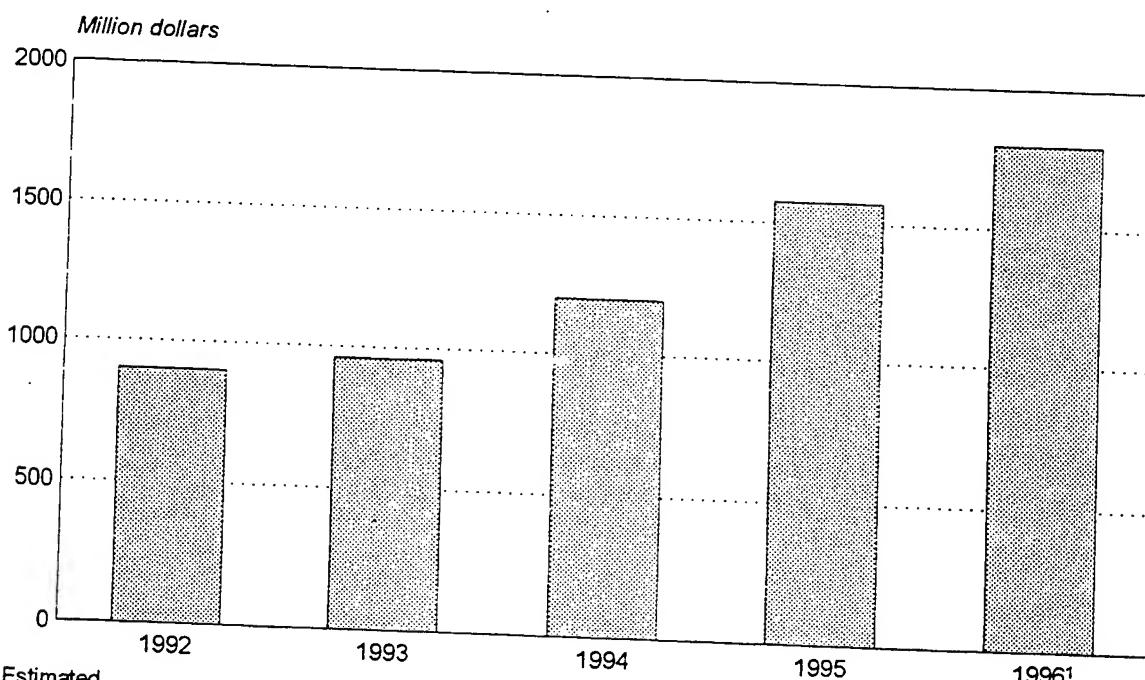
Foreign production facilities of U.S. capacitor and resistor manufacturers

Company	Manufacturing facilities	Production-sharing facilities
AVX	Czech Republic, El Salvador, Germany, Ireland, Israel, Singapore, United Kingdom	Mexico
Kemet	(¹)	Mexico
Vishay	Canada, Czech Republic, France, Germany, Israel, Portugal, United Kingdom	Mexico
Bourns	China, Costa Rica, Ireland, Taiwan, United Kingdom	(¹)
Aerovox	(¹)	Mexico

¹ Not available.

Source: Compiled by the staff of the USITC.

Figure 5-13
Capacitors and resistors: U.S. exports, 1992-96



¹ Estimated.

Source: Official statistics of the U.S. Department of Commerce, excepted as noted.

and resistor manufacturers are changing from devices that are attached by metal leads to those that can be soldered directly to the board.²¹² Because of their smaller size, surface mounted devices (SMDs) require less space on a PCB than conventional components, thus allowing for greater component density on circuit boards. Higher component density enables more functions or features to be offered in the same size unit and allows manufacturers of electronic systems to reduce the size of their end products. Also, the assembly of SMDs onto PCBs may be automated by means of computer-controlled "insertion" or "placement" machinery that can significantly reduce the time needed to assemble electronic equipment. Attaching directly to the PCB, SMDs allow for improved equipment reliability, better vibration performance, and greater immunity to electromagnetic interference.²¹³ According to industry representatives, SMDs are displacing leaded devices and most major U.S. capacitor and resistor manufacturers have converted or are in the process of converting production to surface mount technology (SMT) in those component types that require size reduction.²¹⁴

The pressures toward miniaturization have resulted in components becoming increasingly difficult to handle and assemble onto PCBs. Newer generation components are so small that their mass is often insufficient to hold them in place on a board for attachment.²¹⁵ They are easily damaged and difficult for automated assemblers to grasp and manipulate. These handling challenges have resulted in the need for alternative methods of assembly, and innovations in packaging have recently offered some creative solutions. New trends include resistor networks, resistor arrays, and integrated passive components. Resistor networks contain as many as 23 resistors in a package and are similar to integrated circuits in appearance.²¹⁶ Resistor arrays are comprised of as many as four resistors but are not packaged. Integrated passive components combine capacitors and resistors in one package. These products, by incorporating a number of components in one piece, use less board space and offer the added benefit of a larger individual piece that is easier and less time consuming to mount on a PCB than the equivalent number of individual components. Currently, networks and arrays cost more than individual components, but, with increased production, the cost difference is expected to narrow. Many U.S. producers such as AVX and Bourns, as well as a number of importers, are introducing these products.

The U.S. capacitor and resistor industries face strong international competition. Passive components are mature products, largely interchangeable, and extremely price sensitive. According to industry sources, customer service and cost are the primary determinants in most sales, and U.S. producers have certain advantages and disadvantages in these areas.²¹⁷ As noted earlier, U.S. producers are mostly merchant and concentrate in the production of a limited variety of products. By devoting their resources toward a narrow line of products, U.S. companies can achieve greater economies of scale and also concentrate R&D and capital expenditures. For example, AVX, Kemet, and Vishay have decided to concentrate on the production of multilayer ceramic and tantalum capacitors. These types of capacitors are now the fastest growing segments of the world capacitor market, and as a result these companies appear well positioned to benefit

²¹² U.S. capacitor industry representatives, interviews by USITC staff, Myrtle Beach, SC, Feb. 11, 1997.

²¹³ USITC, *Industry and Trade Summary: Capacitors*, p. 1.

²¹⁴ U.S. capacitor industry meeting, interviews by USITC staff, Feb. 11, 1997. Though a majority of U.S. production in capacitors and resistors is consumed in information technology products, a sizable portion of production is consumed in industrial applications. In these industrial applications, conserving board space is not usually a concern, and as a result there has been little pressure toward miniaturization or SMT in these types of capacitors and resistors.

²¹⁵ Heidi Elliot, "Honey, They've Shrunk the Passives Again."

²¹⁶ World Wide Web, retrieved Jan. 1, 1997, Electronic Buyers' News, <http://www.techweb.com/se/search>, Bettyann Liotta, "An Array of Resistor Alternatives," *Electronic Buyers' News*, Mar. 11, 1996, and World Wide Web, retrieved Feb. 2, 1997, Electronic Buyers News, <http://www.techweb.com/ebn/section/passives.html>, Gina Roos, "Philips' IPCs to Ease Space Constraints," *Electronic Buyers' News*.

²¹⁷ U.S. industry representatives, telephone interviews by USITC staff, Jan. 1997.

from the existing and future consumption trends. In addition, these companies have also made a commitment to convert to SMT, which appears to be the mounting technology of choice for the immediate future.²¹⁸

However, concentration in production also has a disadvantage vis-a-vis foreign competitors which are often vertically integrated firms producing broad lines of components and end-products. According to industry representatives, the primary purchasers of passive components, electronics OEMs, are increasingly interested in dealing with a limited number of suppliers for all of their passive component needs.²¹⁹ Foreign firms are often able to offer an entire line of passive components while most U.S. producers manufacture only a few products and cannot individually fulfill that need. As noted earlier, U.S. companies are finding ways of getting around their production concentration to meet the needs of the OEM customers. For example, Bourns produces only a few types of resistor products in the United States but has been able to round out its product line by importing other types of resistors from Asia and reselling them under its name.²²⁰ AVX has a similar arrangement with Kyocera to sell Kyocera components in the United States.²²¹ Vishay has also broadened its product offerings largely through acquisition. Vishay has purchased a number of component manufacturers and can now offer a broad line of products. Vishay has broadened its product mix while still allowing for some degree of specialization by permitting the acquired companies to continue output of the products in which they excel.²²²

Capacitors and resistors are marketed through a variety of channels, including distributors, independent sales representatives, and direct sales by company salesmen.²²³ Distributors purchase and take possession of the components from the producers and then resell to customers. Independent sales representatives facilitate sales between customers and capacitor and resistor producers, but do not take possession of the products and are usually paid solely on a commission basis. Many companies also maintain regional sales staffs in important locations to provide technical and sales support.²²⁴

U.S. producers compete on customer service through closer relationships with their customers and the increased use of tools such as electronic data interchange (EDI). EDI is an automated program that provides for scheduling deliveries, placing orders, and electronic payments. OEMs are now commonly notifying component suppliers well in advance of their prospective new products and resulting component needs. Closer working relationships often require OEMs to lock into partnership agreements with component manufacturers and the use of EDI. These agreements can result in shorter lead times, greater flexibility in scheduling, a reduction of inventory levels, and shorter cycle times.²²⁵ Many U.S. producers as well as foreign suppliers have already adopted EDI and closer supplier/customer relationships. To compete in a market where products are almost perfectly substitutable, continued innovation in customer service may be required to succeed.

In regard to price competition, the United States has relatively high labor rates and is therefore at a relative disadvantage in terms of production costs. As noted earlier, U.S. firms are addressing this problem largely through the increased use of automation and production sharing. According to industry representatives, U.S. companies are increasingly replacing labor with automated manufacturing processes to

²¹⁸ U.S. capacitor industry representatives, interviews by USITC staff, Myrtle Beach, SC, Feb. 11, 1997.

²¹⁹ U.S. industry representatives, telephone interviews by USITC staff, fall/winter 1996.

²²⁰ U.S. industry representatives, telephone interviews by USITC staff, Jan. 1997.

²²¹ U.S. industry representatives, interview by USITC staff, Raleigh, NC, Sept. 18, 1996.

²²² U.S. industry representatives, telephone interviews by USITC staff, fall/winter 1996.

²²³ U.S. industry representatives, telephone interviews by USITC staff, Jan. 1997.

²²⁴ Ibid.

²²⁵ World Wide Web, retrieved Jan. 17, 1997, Electronic Buyers' News, <http://www.techweb.com/se/search>, Gina Roos, "Buying Strategies, How to Buy Resistors," *Electronic Buyers' News*, Jan. 17, 1997.

lower production costs and increase productivity and product quality.²²⁶ For those areas of the manufacturing process that still require significant labor input, especially assembly and packaging, many companies have established affiliate facilities in low labor-rate areas. AVX, Kemet, and Vishay have all established facilities in Mexico for production sharing. According to these companies, production sharing facilities have allowed them to lower production costs and remain competitive in the face of foreign competition.

Foreign Industry Profiles

Japan

Japan is the world's dominant producer of capacitors and resistors. Production increased from \$6.3 billion to an estimated \$7.8 billion during 1992-96.²²⁷ Much of Japanese capacitor and resistor production is incorporated into consumer electronics or exported. The structure of the Japanese industry is quite different from that of the U.S. industry. Japanese producers are often much larger than their U.S. competitors and often manufacture a wide variety of other electronic products. The largest Japanese capacitor producers include Murata, TDK Corp., Panasonic, Nippon Chemi-con, Nichicon, Kyocera, Hitachi, and Matsuo. Major Japanese resistor manufacturers include Rohm, KOA Speer, Panasonic, Fujitsu, Kyocera, and Susumu.²²⁸ Japanese capacitor and resistor producers are usually closely integrated with Japanese manufacturers of consumer electronics, computers, and communications equipment, and as a result there is a high degree of captive consumption.²²⁹ High levels of captive consumption, as well as significant product diversification, may offer advantages in guaranteed demand and the financial resources to sustain market downturns.

Many of the major Japanese producers are active in international trade, and from 1992-96 Japanese exports rose from \$2.2 billion to an estimated \$3.6 billion.²³⁰ The roughly 65-percent growth in exports far exceeded the 24-percent growth in production. In order to lower production costs and better serve foreign markets, Japanese firms have also become active in establishing foreign production facilities. Kyocera purchased AVX, and Murata and Panasonic maintain capacitor manufacturing facilities in the United States. In addition, Matsushita entered into a joint venture with Siemens of Germany to produce components in the EU, and Nissei Electric of Japan purchased Black and Decker's EU production facilities.²³¹ Numerous Japanese producers have also begun to move production facilities to Asian countries. This effort in large part has been to follow the continuing movement off shore of Japanese consumer electronics manufacturing.²³²

European Union

The European Union is currently the world's third largest manufacturer of capacitors and resistors. EU production grew from \$2.1 billion to an estimated \$2.3 billion during 1992-96.²³³ Production was largely

²²⁶ U.S. capacitor industry representatives, interviews by USITC staff, Myrtle Beach, SC, Feb. 11, 1997.

²²⁷ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

²²⁸ "The List," *Electronic Buyer's News* and Dodwell Marketing Consultants, *Key Players in Japanese Electronics Industry* (Tokyo, Japan: Dodwell Marketing Consultants, 1985), pp. 322-323.

²²⁹ *Japan Electronics Almanac '95/'96* (Tokyo, Japan: Dempa Publications, Inc., 1995), p. 125.

²³⁰ Estimated by USITC staff based on United Nations Trade Series D.

²³¹ U.S. industry representative, telephone interview by USITC staff, Feb. 27, 1997.

²³² *Japan Electronics Almanac '95/'96*, p. 133.

²³³ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

concentrated in Germany, the United Kingdom, and the Netherlands, which are centers for EU electronic systems manufacturing. The capacitor and resistor industries in the EU are a mix of foreign- and EU-owned firms, and production is dominated by a relatively small number of producers.²³⁴ Major capacitor manufacturers include Siemens/Matsushita, Philips, Vishay, AVX, Thompson-CSF, WIMA, Arcotronics, VOX/RIFA, and ISKRA. Major resistor manufacturers include Philips, Vishay, Siemens, Beyschlag, Welwyn, Beckman, and Vitrohm.²³⁵

Many of the major EU-owned producers maintain significant levels of internal consumption. In addition, a number of major foreign-owned EU producers were established to serve that market. As a result, the EU exports a smaller share of its production relative to other major producers. From 1992-96 EU exports of capacitors and resistors are estimated to have grown from \$900 million to \$1.1 billion.²³⁶

Other Producers

Korea, China, Singapore, and Taiwan are the largest of the emerging capacitor and resistor manufacturers. From 1992-96 their combined production is estimated to have grown from \$1.7 billion to \$3.5 billion.²³⁷ Among the large Korean producers are Samhwa Capacitor Co.; vertically integrated electronics conglomerates such as Samsung, Lucky Goldstar and Daewoo; and several Japanese transplants.²³⁸ Taiwan is the group's largest producer of resistors, with 1996 production estimated at \$230 million.²³⁹ Resistor production in Taiwan is highly fragmented with over 150 producers. Some of the largest companies include Yageo, Ty-Ohm, Ever Ohms Industry, and First Resistor and Condenser Co. Ltd.²⁴⁰ In both capacitors and resistors, China is the fastest growing producer, a trend that appears likely to continue as a number of companies in the region are transferring production to China to take advantage of lower production costs.²⁴¹ In addition to multinational firms, several Chinese state-run companies also produce and export capacitors and resistors. Though reportedly of suspect quality, Chinese components are often marketed at prices well below other major manufacturers.²⁴²

During 1992-96 exports of capacitors and resistors from Korea, China, and Singapore, and Taiwan more than doubled, rising from \$1.2 billion to an estimated \$2.6 billion. The rate of growth in exports from these Asian countries was slightly greater than that of the United States and much higher than the growth in Japanese and EU exports.²⁴³

²³⁴ U.S. industry representative, telephone interview by USITC staff, Feb. 27, 1997.

²³⁵ Letter from U.S. industry representative to USITC staff, Mar. 7, 1997.

²³⁶ Estimated by USITC staff based on data from Eurostat and European Commission, *Panorama of EU Industry*, p. 10-9.

²³⁷ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996.

²³⁸ USITC, *Industry and Trade Summary: Capacitors*, p. 7.

²³⁹ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996.

²⁴⁰ Mark LaPedus, "Yageo Makes Growth Move."

²⁴¹ World Wide Web, retrieved Jan. 17, 1997, Electronic Buyers' News, <http://www.techweb.com/se/techsearch>, Mark LaPedus, "Taiwan Ups the Ante-Despite Higher Demand, Suppliers Plan Price Cuts," *Electronic Buyers' News*, Feb. 13, 1995.

²⁴² World Wide Web, retrieved Feb. 11, 1997, Electronic Buyers' News, <http://www.techweb.com/se/techsearch>, Mark LaPedus and Sandy Chen, "China Passives: Looking Abroad," *Electronic Buyers' News*, Jan. 27, 1997.

²⁴³ Estimated by USITC staff based on United Nations Trade Data Series D and Elsevier, *Yearbook of World Electronics Data*, 1994 and 1996.

Global Market Profile

The production of capacitors and resistors closely follows the demand for the electronic systems in which they are incorporated. Chief among these are computers, telecommunications equipment, consumer electronics, and automobiles which are estimated to account for over three-quarters of consumption. Electrical systems such as air conditioners, motors, fluorescent lighting, and compressors also require passive components but are estimated to account for less than a one-quarter of capacitor and resistor consumption. There is a particularly close relationship between semiconductors and passive components, because semiconductors require passive components in order to function.²⁴⁴ A change in the demand for semiconductors generally results in a corresponding change in the demand for capacitors and resistors. This relationship is especially pronounced for ceramic and tantalum capacitors because of their use in the manufacture of semiconductor-intensive information technology products, while aluminum and film capacitors are most often used in industrial products.

U.S. Market Profile

The market for capacitors and resistors in the United States increased irregularly during 1992-96, with noticeable increases in 1994 and 1995 and a decline in 1996. The U.S. market grew from \$2.1 billion in 1992 to \$2.4 billion in 1996.²⁴⁵ Growth in the sector was driven by increased demands for information technology products, especially computers and telecommunications equipment. However, in 1996 the semiconductor market suffered a decline because high growth rates that occurred in the sale of information technology products in 1995 did not match expectations in 1996. As the market for capacitors and resistors closely follows the market for semiconductors, a similar decrease in growth occurred among these passive components.

Although consumption levels reflected little change, imports of capacitors and resistors increased noticeably between the years 1992 and 1996. In 1996, imports of these passive components into the United States equaled nearly \$1.7 billion, compared with approximately \$1.1 billion in 1992, representing an estimated average annual growth of roughly 11.5 percent.²⁴⁶ In addition, the import to consumption ratio has increased dramatically since 1992. In 1992, imports made up slightly over half of all U.S. consumption of capacitors and resistors. By 1996, however, the percentage of imports to consumption increased to an estimated 71 percent. This rise primarily stemmed from increased use of production-sharing relationships with assemblers in Mexico as well as an increase in the number of products imported from Asia for relabeling or direct sale in the United States. U.S. tariff rates on January 1, 1999 on imports of capacitors are scheduled under the GATT Uruguay Round reductions to equal 9 percent while imports of parts for capacitors will equal 3.5 percent (table 5-5).²⁴⁷ For resistors, most imports will be dutiable at a rate of 6 percent. However, fixed and wirewound resistors for a power handling capacity of over 20w or more will be dutiable at 3 percent. In addition, other variable resistors will be dutiable at either zero or 4.8 percent, depending on the type. Because of the commodity nature of these products, ITA duty elimination is likely to result in increased market access opportunities.

²⁴⁴ World Wide Web, retrieved Jan. 23, 1997, *Electronic Business Today*, <http://www.ebt.mag.com/issue/9701/01passive.htm>, Heidi Elliot, "Passives Sing a Happy Tune," *Electronic Business Today*, Jan. 23, 1997.

²⁴⁵ Estimated by USITC staff based on official statistics of the USDOC.

²⁴⁶ Ibid.

²⁴⁷ *Most-Favoured-Nation Tariff Schedules*.

Table 5-5
Final Uruguay Round tariffs on capacitors and
resistors for ITA participants

Participants	Ad Valorem Rate ¹ as of Jan. 1, 1999	
	Capacitors	Resistors
Australia	15-17	15
Canada	5.1	0
Costa Rica	(²)	(²)
Estonia	0	0
European Communities (15)	2.7-3.7	2.7
Hong Kong	0	0
Iceland	(²)	(²)
India	40	40
Indonesia	40	40
Israel	5-12	(²)
Japan	0	0
Korea	13	13
Macau	0	0
Malaysia	0-30	0
New Zealand	30	0-25
Norway	3	3
Romania	35	35
Singapore	10	10
Switzerland	0.2-1.3	0.1-2.7
Taiwan ³	1.25-12.5	1.25-3
Thailand	(²)	(²)
Turkey	8	14.1
United States	3.5-9	0-6

¹ Ranges are indicative of the range of ad valorem rates on all products in the sector.

² Not available.

³ Taiwan has not yet acceded to the WTO. Tariff rates are based on DOC documents showing 1992 unbound rates.

Source: *Most-Favoured-Nation Tariff Schedules, Annexes to Final Act Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations (Marrakesh Protocol)*, Marrakesh, Apr. 15 1994 and U.S. Department of Commerce working documents.

The Commission has received submissions from a number of U.S. capacitor and resistor producers. All of the submissions contained statements opposing the inclusion of capacitors and resistors in the ITA. In general, these manufacturers are concerned that the elimination of U.S. tariffs will result in substantial import growth to the detriment of the U.S. industry. Further, growth in imports would not be offset by increased opportunities for export based on ITA duty elimination because of the continued existence of non-tariff barriers in other major markets. Submissions by the capacitor and resistor industries can be seen in their entirety in appendix F.

Foreign Market Profiles

Japan

Consumption of capacitors and resistors in Japan remained relatively unchanged at roughly \$4.5 billion during the period.²⁴⁸ In addition, as in the United States, demand for semiconductors declined in 1996 leading to a decline in the demand for capacitors and resistors. In comparison, imports of these passive components increased steadily from about \$140 million in 1992 to an estimated \$300 million in 1996.²⁴⁹ This increase in imports translates to an average annual growth rate of nearly 20 percent. Despite high import growth rates, the import to consumption ratio in Japan remains extremely low. In 1992, imports comprised slightly over 3 percent of consumption, increasing to an estimated 7 percent of consumption in 1996. Relative to other markets, the import-to-consumption ratio for capacitors and resistors is dramatically lower than corresponding ratios in the United States, EU, and other Asian countries. According to U.S. industry representatives, the major Japanese consumers of passive components, large electronics OEMs, are resistant to purchasing products from outside of their industrial groupings.²⁵⁰ Japanese passive component imports are mostly limited to products for which there is no domestically produced equivalent.²⁵¹ Japan has already eliminated its tariffs on capacitors and resistors, and as a result the ITA will not result in increased market access opportunities.

European Union

The countries that make up the EU accounted for an estimated \$3 billion in consumption of capacitors and resistors in 1996.²⁵² Since 1992, when consumption equaled \$2.5 billion, the annual average growth rate equaled an estimated 5 percent. Growth in the sector generally followed increased demand in the computer, telecommunications, and automobile sectors.²⁵³ EU imports of capacitors and resistors are estimated to have grown during 1992-96 from \$1.3 billion to \$1.7 billion.²⁵⁴ Imports represent roughly 60 percent of the EU market. The principle exporters to the EU market are Japan and the United States, which account for approximately one-half of all EU imports.²⁵⁵ In the absence of an ITA, imports of capacitors into the EU on January 1, 1999 will be dutiable at rates ranging from a high of 3.7 percent to a low

²⁴⁸ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996 and United Nations Trade Series D.

²⁴⁹ Ibid.

²⁵⁰ U.S. industry representatives, telephone interviews by USITC staff, fall 1996 and winter 1997.

²⁵¹ Ibid.

²⁵² Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996 and United Nations Trade Series D.

²⁵³ Industry representative, interview by USITC staff, Washington, DC, Mar. 7, 1997.

²⁵⁴ European Commission, *Panorama of EU Industry*, pp. 10-9.

²⁵⁵ Ibid, pp. 10-11.

of 2.7 percent. For resistors, import tariffs will equal 2.7 percent.²⁵⁶ The ITA should result in a slight increase in market access. Further, as with semiconductors and PCBs, EU enlargement will also bring increased market access opportunities to foreign producers.

Other Markets

Korea, Taiwan, Singapore, and China accounted for consumption of approximately \$3.6 billion of capacitors and resistors in 1996.²⁵⁷ In 1992, these four countries consumed an estimated \$2.1 billion of passive components which translates to an annual average growth rate of roughly 14 percent during 1992-96. Growth in the market is fairly closely tied to growth in the consumer electronics, computers, and telecommunications industries, and for Korea and China, the automobile sectors.²⁵⁸ Imports of capacitors and resistors collectively grew at about the same rate as consumption during the period. Imports of these products equaled an estimated \$2.7 billion in 1996, increasing from \$1.6 billion in 1992. The import to consumption ratio has been fairly high throughout the period as these countries produce a smaller variety of components and have to import those not domestically produced. In the absence of an ITA, tariffs on capacitors and resistors are scheduled to be 13 percent in Korea and 10 percent in Singapore as of January 1, 1999.²⁵⁹ As China and Taiwan are not WTO members, their rates are not bound, and may change at any time. In 1992, China's base tariff rates on capacitors and resistors ranged from a high of 40 percent to a low of 15 percent. Taiwan's tariff rates in 1992 were significantly lower than China's, with capacitors and resistors dutiable from a high of 12.5 percent to a low of 1.25 percent. Based on duty elimination under the ITA, market access opportunities should increase substantially in Taiwan, Singapore, and Korea. Market access will remain unchanged in China, since it is not an ITA signatory.

²⁵⁶ *Most-Favoured-Nation Tariff Schedules*.

²⁵⁷ Estimated by USITC staff based on Elsevier, *Yearbook of World Electronics Data*, 1996 and United Nations Trade Series D.

²⁵⁸ Industry representative, interview by USITC staff, Washington, DC, Mar. 7, 1997.

²⁵⁹ *Most-Favoured-Nation Tariff Schedules*.